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INCREASE IN WATER FACILITIES TO MEET WARTIME DEMANDS AT NEWPORT, RHODE ISLAND

BY HAROLD E. WATSON*

[*Read February 27, 1947.*]

As was the case with many other localities, Newport, R. I., found it necessary to increase the facilities of the public water supply to meet the requirements of new and greatly expanded military establishments during the war.

Before considering the extension of the water supply, it is necessary to consider briefly the development of the water-supply system as it existed prior to the war.

The city of Newport occupies the southern end of the island of Rhode Island. This island, situated in the lower part of Narragansett Bay, comprises, besides the city of Newport, the towns of Middletown and Portsmouth, located in the central and northern portions of the island, respectively. The island is about 12 miles long and 4 miles wide and, in general, is rolling country, much of which is at relatively low elevations.

The Newport Water Works, which is the only public water supply on the island, furnishes water to the city of Newport, several military establishments, and part of the town of Middletown, Portsmouth being without a public supply.

The supply is derived from six storage reservoirs, the location of which is shown on Figure 1. These reservoirs are relatively shallow—about 9 to 10 ft in average in depth some cases. They are enclosed by about 4½ miles of dams, or perhaps they would be more properly called dikes. Adjacent to two of these, Easton's North and South Ponds, are located the main pumping station and treatment plant.

Some two miles east of the main pumping station are located

*Commissioner, Newport Water Works, Newport, R. I.

two more reservoirs, Nelson's Pond and Gardner's Pond. An auxiliary pumping station is situated beside Nelson's Pond. From this station, water from the above-mentioned ponds may be pumped to the main station for treatment.

Water from the two remaining raw-water reservoirs, St. Mary's Pond and Sisson's Pond, located approximately in the middle of the island, is allowed to flow by gravity through a canal and brooks to Easton's Pond, whence it is pumped into the filter plant at the main station. The treatment plant, of conventional horizontal-flow type, consists of baffle-plate aerators, coagulation basins with a capacity of approximately 1 mil gal, six filter units, and appurtenant equipment. The rated capacity of the plant is 6 mgd. This station is operated continuously, 24 hours a day.

Pressure in the city is maintained by a filtered-water reservoir, situated about 1¼ miles from the main station. This reservoir has a capacity of 8 mil gal, constituting a reserve supply of filtered water.

These raw-water reservoirs have a total storage capacity of approximately 1,500 mil gal and receive the run-off from about 8½ sq mi of watershed. Due to the small size and general topography of the island, it has been necessary to utilize practically all of the drainage available and the reservoirs are necessarily located at low elevations, the high-water level of two being only about 12 ft above mean low-tide level and their location but 300 to 400 ft from the ocean. Two others are about 17 ft above mean low tide, while the last pair is higher and farther inland, at elevations of 180 and 163 ft.

This, then, is a brief description of the supply works as it existed prior to the war. The population served was about 30,000 and the pumping averaged about 3 mgd.

At the time of the first World War, when, during 1918, the water works supplied a considerably increased wartime population and received the lowest rainfall recorded up to that time, measures were taken to conserve water and the supply proved to be adequate. It was then apparent, however, that with a cycle of dry years and an expanded population there was an insufficient factor of safety.

Some years later the well-known expedient of 100% metering, preceded by a pitometer survey, was undertaken. This procedure

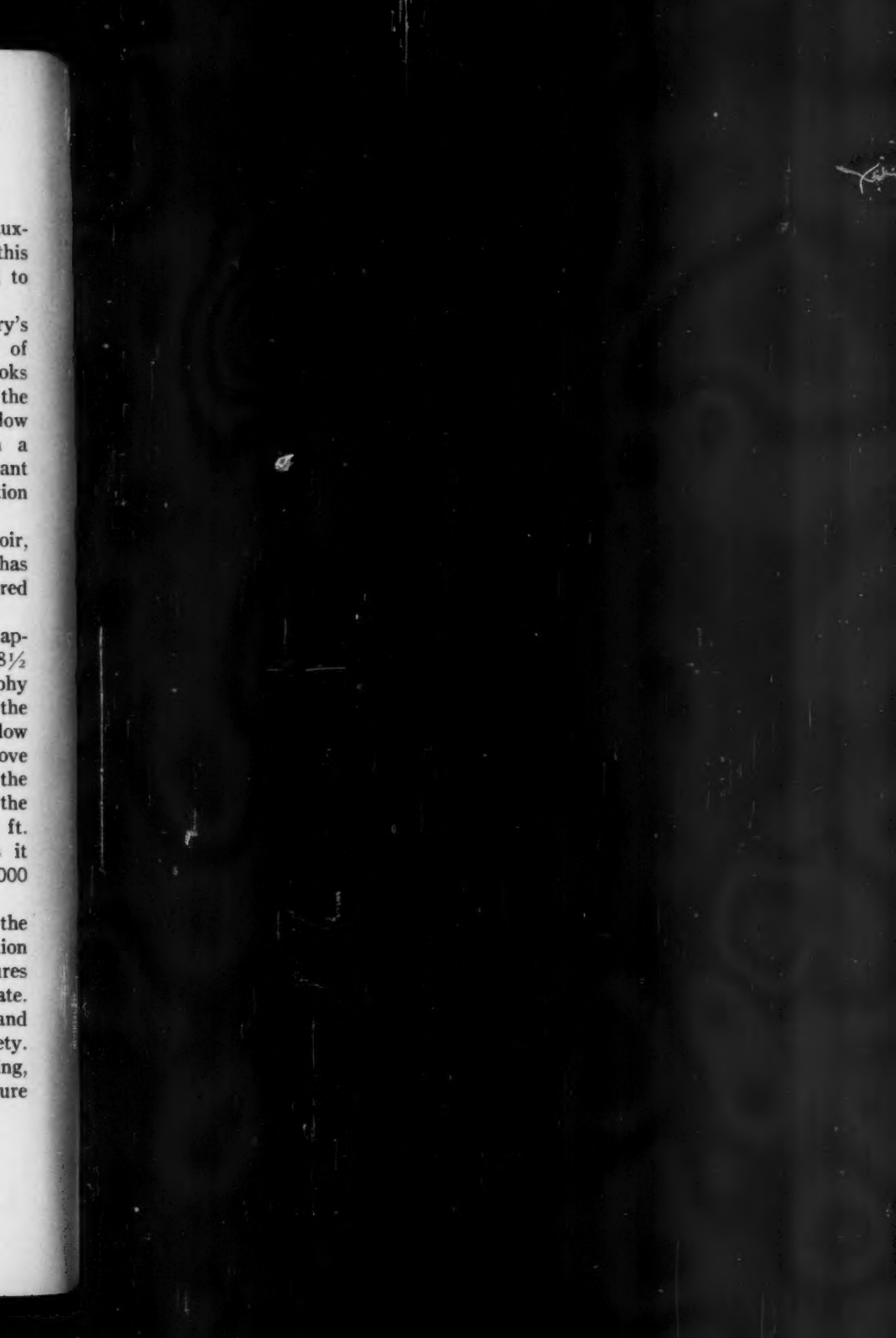


Figure 1

NEWPORT WATER WORKS

PLAN SHOWING

LOCATION OF RESERVOIRS, PUMPING STATIONS

MAIN SUPPLY AND DISTRIBUTION MAINS

AND

CONNECTIONS TO U.S GOVERNMENT WATER FACILITIES

SCALE 1" = 1000' FEB. 24, 1944

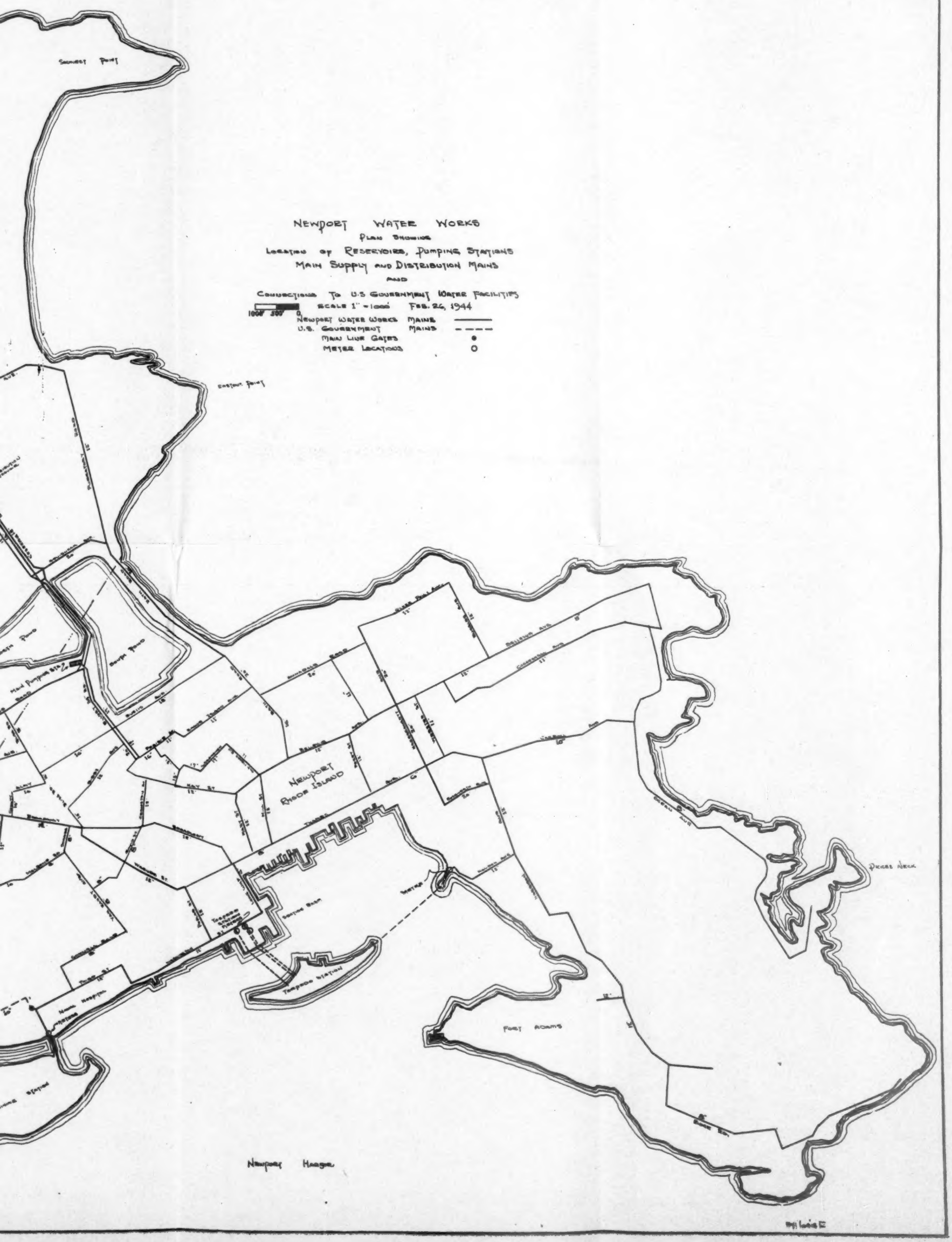
1000' 500' 0

NEWPORT WATER WORKS MAINS ———

U.S. GOVERNMENT MAINS – – – –

MAIN LINE GATES •

METER LOCATIONS O



MIDDLETOWN – RHODE ISLAND

Figure 1

NEWPORT WATER WORKS

PLAN SHOWING

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NEWPORT WATER WORKS MAINS ———
U.S. GOVERNMENT MAINS – – – –
MAIN LINE GATES ⊗
METER LOCATIONS ○

MIDDLETOWN – RHODE ISLAND

NEWPORT
RHODE ISLAND

Newport Harbor

TIVERTON – RHODE ISLAND

PORTSMOUTH – RHODE ISLAND

Sakonnet River

Poppasquash Rd.

Bristol

Portsmouth R.I.

Middletown R.I.

St. Mary's Reservoir

Green Reservoir

Green Chambers Chlorination System

Lawton Valley Reservoir

Lawton Valley Pumping Station

Lawton Valley Water Treatment Plant

Chlorination Equipment

West Main Road

To Newport

Lawton Valley

Hunter Road

Lawton

Narragansett Bay

cut avoidable losses to a minimum and reduced the amount of water pumped to such a point that the available supply was adequate and safe for normal use for some years to come.

In 1941, however, the rainfall record was broken by a new low—the lowest of a 41-year period—namely, 32.09 in., compared with an average of 42 in. and the 1918 minimum of 33.18 in. Military activities began to increase and water consumption to go up and it was apparent that increased water facilities must be obtained.

Studies of possible methods and plans of augmenting the water supply had been made and negotiations with the F. W. A. were initiated, which resulted in the starting of work on one of the main projects for increasing the supply. This was the development of the sole undeveloped watershed on the island and consisted of the construction of a dam at Lawton's Valley, so called, which would impound the water from a watershed of about 1¼ sq mi and produce a storage reservoir of 400-mil gal capacity. In conjunction with this, plans called for a treatment plant with a nominal capacity of 4 mgd, a treated-water reservoir of 4-mil gal capacity, and a small pumping station on the downstream side of the dam, to raise the raw water to the treatment plant.

At this point some reference should be made to the method of operating the system before this new development was started.

The two outlying, high-level reservoirs, St. Mary's and Sisson's Ponds, had originally been connected with the Newport system by a 17-in. pipe, of the thin, wrought-iron shell and cement type, about 3½ miles long. Years ago it had been used to supply takers along the line, as well as to get the water from these outlying reservoirs into the Newport system. When its use for raw water was abandoned, treated water was supplied to it by means of a booster pump at Pumping Station No.1, the direction of the flow being reversed. To prevent the raw water from entering the pipe at its outer end, an existing screen chamber of concrete was made use of in the following manner. There was one solid division wall in the chamber and the piping was so arranged that the raw water could be stopped on one side and the treated water on the other. The elevation of the pond was too low to permit raw water to flow over the baffle. If more treated water was pumped than used, the excess could flow over the baffle and into the pond.

Approximately the last mile of this pipe line was without takers and, being open to the atmosphere at the screen chamber, it functioned as a standpipe. With this arrangement it was necessary, in order to get the water from these two reservoirs to the treatment plant, to let it run by gravity through a canal and thence into the brook feeding Easton's North Pond. This, of course, entailed losses of water in the flow down the brook and losses in power, because the water went from an average elevation of about 170 ft to an elevation of about 12 ft. It was, consequently, a part of the Lawton's Valley project to lay pipe from these reservoirs to the new treatment plant and thus to permit the water to run down by gravity and save as much head as possible.

Thus the treatment plant at this development was placed at an elevation of 154 ft. The locations of the pumping station, treatment plant and distributing reservoir are, I think, unique, in that all three are on the same state highway and all are included in a horizontal distance of 1,350 ft but the elevations range from 73 to 200 ft.

The dam at Lawton's Valley is an earth dam with concrete core-wall. It is 2,604 ft long and 16 ft wide at the top, with the spillway elevation at 112 ft. A concrete intake tower and a 30-inch concrete outlet conduit are provided. The pump-house, located close to the downstream slope of the dam, is of brick and concrete and is equipped with two electrically-driven centrifugal pumps. One of these pumps has an extended shaft, for coupling to a gasoline motor in the event of power failure. These pumps raise the raw water from the impounding reservoir to the treatment plant. The treatment plant is of mill-type construction and, due to wartime restrictions, much was made of mass concrete and wood, including waterproof plywood. The floors are wood, covered with asphalt tile. The settling basins, storage basins and filter beds have unreinforced, gravity wall sections. Only in the wash-water troughs was reinforcing used. A second floor provides storage space for chemicals and there is a freight elevator for handling them. This plant employs the up-flow sludge-blanket type of coagulation by means of a Permutit (Spaulding) Precipitator. It is, we believe, the first plant of this type used in New England for treating a public water supply.

The water entering the plant receives the usual chemical doses

and then passes through a paddle mixer to the precipitators, of which there are two. Leaving the precipitator, the water passes to a retention basin, supplying about 3 hours' retention at the normal rate of 4 mgd. It then passes on to the filters of conventional type, of which there are four units of about 1¼-mgd capacity. The clear-water well is located outside of the building, because there was much ledge and such a location saved considerable rock excavation.

Due to wartime restrictions, all gates are manually operated. The flow through the plant, however, is semi-automatic in control. For example, if one filter is shut down for washing, the rate of flow through the remaining three will gradually increase, to maintain about the same delivery to the clear well and, contrariwise, the rate of flow will gradually decrease when the filter is returned to service. The plant is equipped with all the apparatus required to feed alum, lime, clay, ammonia, chlorine, sulphur dioxide and calgon. There is also a fully equipped laboratory.

In the basement of the building, there is housed a pumping plant for raising the treated water to the distribution reservoir. This comprises two electrically-driven centrifugal pumps—one of 4-mgd capacity and one of 2-mgd capacity. There is also a gasoline motor for quick coupling to the extended shaft of the larger of these pumps, for use in the event of power failure, and a gasoline-motor generator set, to provide current for lights and a few small motors.

The distribution reservoir is located on a hill and the elevation of its high-water line is 200 ft above mean low water. It is also of concrete, with unreinforced, gravity wall sections. It has a capacity of 4 mil gal and, due to shortage of necessary materials, is not covered.

In order to integrate this supply with the original supply, it was necessary to lay a 24-in. pipe line from the new distributing reservoir a distance of about 4 miles to points of connection with the existing distributing system. As connections were made at four different places, considerable elasticity of control was secured. Branches from this main were laid to various military establishments along its run. All services from the older main were transferred to the new line, the original old main being thus released for use in transferring raw water from the upper to the lower reservoirs, when and if necessary.

During the initiation of this project, consumption of water rose steadily and both average and peak demands were increasing. The best estimates which could be obtained of the possible ultimate demand showed clearly that further increases in supply would have to be made. Furthermore, while, as previously mentioned, the work was started in June, 1942, it would not be finished in time for the reservoir to fill the following winter. Consequently, at best it would be 1944 before any benefit would accrue from this development. Thus, we were still faced with an impending water shortage.

The best answer seemed to be two more projects. The first was to raise the height of the Gardner's Pond dam about 5 ft and thus provide increased storage capacity of 150 to 200 mil gal, a large pipe line from the point of collection to the reservoir being installed at the same time. The second new project was to develop a supply on the mainland and pipe it across to the island. As it had been felt by the water works and many others for some years that the most logical mainland supply for Newport was the development of Nonquit Pond in Tiverton, this plan was restudied and negotiations with the F. W. A. resulted in the starting of work almost immediately on these two supplementary projects. Since the raising of the dam at Gardner's Pond was the project which would furnish additional water most quickly, this was completed sufficiently to enable the storage of 100 mil gal more than before.

The second supplementary project, that of developing Nonquit Pond, was much more ambitious. This was a salt-marsh pond and, at the time work was started, the water in it had an average chloride content of 1,800 ppm. Accordingly, one of the first problems was desalting. This was accomplished by setting up a 10-mgd pump and, as soon as the coffer-dam upstream from the projected dam was built, pumping to waste was immediately started. By this means, there was quite a rapid and reasonably steady exchange of fresh water for salt water, because, while the pond has a capacity of about 525 mil gal, it is supplied by a watershed of 9.25 sq mi, which is nearly equal to the total of 9.69 for all of the watersheds on the island. Fortunately it was possible, by keeping the pond elevation low, to avoid the building of long dams or dikes. Hence the construction at Nonquit Pond project consisted of the following: a

pumping station built of brick and concrete, a concrete intake, and a semi-circular dam of concrete, about 110 ft long.

The elevation of the spillway is 7 ft above mean low tide and it is provided with flash-boards about 3 ft high. In order to get this water to the island, a 20-inch pipe line, about 3¾ miles long, was laid and about one mile of it had to be laid under the Sakonnet River, so called. This body of water is not a river in the true sense of the word but is really an arm of the sea, lying between the island of Rhode Island and the mainland to the east. This sub-aqueous line was of cast iron with Metropolitan joints and was laid in a 6-foot trench. The maximum salt-water depth over the pipe is about 30 ft. After reaching the island this pipe line was laid to St. Mary's reservoir, where it terminated in a small outlet structure. This made it possible to pump water from Nonquit Pond on the mainland to St. Mary's reservoir on the island, whence it could flow by gravity to the treatment plant at Lawton's Valley or by the old pipe line from St. Mary's reservoir to Easton's North reservoir.

In the station at Nonquit Pond there was installed a centrifugal pump of 3-mgd capacity, driven by a 200-hp electric motor. This plant was placed in operation on the last day of September, 1943, and was in operation continuously until December, 1943, when, due to another record low rainfall, the continued demand and the fact that the Lawton's Valley reservoir had only partly filled up, it seemed highly desirable to increase the amount of water taken from Nonquit Pond, in order to provide an ample supply on the island. We were able to find a second-hand pump and motor with the proper characteristics and the Nonquit station was shut down long enough to install this supplementary equipment. This new installation increased the output from 3 mgd to 4 mgd and it was operated at this capacity until the last of April, 1944. Pumping was resumed in August and continued until the 1944 hurricane, when the entire Nonquit Pond was salted. Shortly after that the Nonquit station was again placed in operation, in order to pump the salt water to waste. This was done by pumping through a blow-off on the force main into the Sakonnet River.

Summary

Due to the wartime demands, the water supply of the city of Newport had to be increased. Several problems were presented, because Newport is on an island and it is impossible to secure a water supply from a neighboring city, because all of the available watersheds on the island, with the exception of one, had already been developed and, finally, because whatever was done had to be done quickly. The required increase in water supply was obtained by means of the following four F. W. A. projects:

1. An earth dam and reservoir impounding the water of Lawton's Valley, a pumping station, a treatment plant, a distributing reservoir and appurtenant piping, to enable the correlation of this new water supply with the existing water supply.
2. The installation of a 24-inch pipe line from the new distributing reservoir to the existing distribution system.
3. The raising of the height of an existing dam to increase the capacity of the reservoir by 150 mil gal.
4. A concrete dam to create an impounding reservoir on the mainland at Nonquit Pond, the building of a pumping station, and a 20-inch pipe line from this station on the mainland to St. Mary's reservoir on the island.

The combined old and new systems make for extreme flexibility of operation; filter and pumping capacity was raised from 6 to 10 mgd; the two plants give the protection of duality to the water supply; the safe yield of the supply was more than doubled, and a generally more efficient operation was achieved.

Discussion

Donald C. Calderwood (Nashua, N. H.). What was the maximum daily consumption during that period?

Harold E. Watson. You mean, the highest in one day during the war?

Mr. Calderwood. Yes.

Mr. Watson. About 7 mil gal.

Warren J. Scott (Hartford, Conn.). How long did it take to pump out the pond that was salted up?

MR. WATSON. You mean, following the hurricane or the original construction?

MR. SCOTT. No; after the hurricane.

MR. WATSON. Well, I am not exactly certain. I know that the hurricane occurred in the fall and we pumped water from that pond and used it in Newport the next summer. I can't remember now the exact time that it took to desalt it sufficiently so that it could be used, but something under, I would say, eight months.

PLUGGING UP LEAKS

BY HERMANN BEHR*

[*Presented February 27, 1947.*]

My remarks will be confined to plugging up the leaks in your organizations, in your operations—leaks which result from the accidents and injuries to the men who are doing the work on your projects. Naturally you are interested in the safety of your workmen but you are also vitally interested in decreasing your overhead costs, in improving your operating efficiency, and definitely interested in reducing your operating costs.

I don't know whether you realize it but, on a nationwide basis, the average cost of an industrial injury is about $250.00, of which your compensation insurance policy covers only about $50.00. The other $200.00 has to be paid for in one way or another by you and covers the replacement and repairing of damaged equipment, the hiring of new employees to replace injured ones, and the retarding of your work schedule. Altogether you can estimate that the invisible red-ink figures on your books will total about $200.00 for every industrial injury to your workmen.

When I say "industrial injury" I mean something more than just a scratch. The average scratch can, of course, be taken care of by first aid. You may send a man to a doctor or you may bring him over to headquarters and give him a little first-aid treatment, but any injury which results in the loss of working time, for which compensation is paid, costs the employer money. It will not be $200.00 on every case but, when you average up at the end of the year, you will find that it comes pretty near $200.00 per case.

The accident frequency in water-works operations is a difficult matter to estimate and I have been unable to locate any statistics that apply. My own company insures many municipalities and we find that the average frequency for public-works operations runs about 20 lost-time injuries per million man-hours worked. The average

*District Safety Director, Lumbermen's Mutual Casualty Co., 260 Tremont St., Boston 16, Mass.

machine shop will run somewhere around 16; a saw-mill will run about 28 to 30; construction work involving buildings—and you are somewhat concerned with that category—will run somewhere around 22. Personally, I feel that it is a mistake to be satisfied with the average accident frequency and I would want my own jobs to show a better-than-average frequency, for the sake of the workmen as well as for the sake of the department's pocketbook.

It is usually the emergency jobs that develop the serious accidents, rather than the normal operations, and so it is only common sense and a wise precaution to use your best men whenever there is a job to be done in a hurry.

There is another side to the whole picture that I would like to introduce right here and that is the question of insurance costs. I don't mean to intimate that we should be interested more in the cost of insurance than the health and welfare of our workmen but, on the other hand, any employer who is critical of his insurance costs and studies the accidents from that point of view is usually successful in keeping his accident-frequency rate down below the average.

Your insurance premium is subject to what is known as "experience rating" and this very roughly is the ratio between the amount of money that you pay the insurance carrier and the amount of money that the insurance carrier has to pay out for injuries to your workmen, for treatment of those accidentally injured on the job. For instance, if the losses on a $10,000 compensation premium run about $6,500.00—and understand that the insurance rates are all made by the State and not by any individual insurance company—your rate is apt to be jumped up and you may find that you are paying for your compensation insurance policy on the basis of $1.75 or more for every $1.00 worth of insurance, which, on the other hand, a well-established and closely-followed safety program would enable you to buy for much less than $1.00.

We insure quite a few municipalities and most of these have operated for quite a few years with substantial experience credits. Pittsfield, West Springfield, Taunton and Andover come to my mind and yet, in spite of their vigilance, every once-in-a-while somebody does something wrong at the wrong time, with the result that an eye is lost, a leg broken or a foot crushed and an otherwise good safety record is spoiled.

There is no secret, no mystic procedure, in setting up a safety program but there are three fundamental principles on which such a program must be founded, if it is to survive and get results. First and most important is to create an active interest in the accident-prevention work; second is a thorough study of the operations, to get all the facts together concerning accident possibilities, and third is to correct faulty or dangerous procedure. Surely there is nothing complicated about this, because all you have to do is to study your operations and find which ones are causing the trouble and then do something, provided, of course, you are interested in the first place. Interest in such a program must come from the front office—from the brass hats at the top—pass on to the superintendents and foremen, and so on down to the workmen. The welfare and safety of the men come first and it is usually true that the department which operates with the best accident record is also the one which operates most efficiently and most economically.

The superintendent or the general foreman must study his operations carefully from the standpoint of safety, as well as production, and then plan his work to eliminate all visible accident hazards. The operating foreman, on the other hand, is the one who is actually in contact with the workmen. He is the man who must insist on compliance with the safety rules, that the men wear their goggles or their hard hats, that small scratches and bruises get prompt first-aid treatment. I have usually found that, where the job superintendent is definitely interested in the safety program, the foremen are also very much interested and they are quite apt to boast of their ability to turn out a good job on time and without injury to the men.

A capable superintendent usually needs no prompting to pick out the principal work hazards on any project but he does not often realize the importance of the social environment, background, race and habits of workmen, all of which have a definite bearing on the job-accident picture. It is not expected that a sick man can do a good job or do work safely, but neither will a man who is worried with troubles at home or who is working on a job that he does not like. These are conditions which the foreman can and should keep in mind and check just as carefully as he does the case of a man who comes on the job with a drink or two under his belt. Men are not inten-

tionally reckless and I firmly believe that there is no such thing as pure carelessness. A foreman who attributes an accident to pure carelessness probably does so because he hasn't taken the time or trouble to study the whole situation thoroughly. If he did so, he would probably find that the workman did not receive proper training before he was put on the job, that he is not physically fit for the work or that he had no definite supervision, to see that he followed previous instructions. No man is careless because he wants to be; he is careless because of some condition that he cannot or will not correct and, unless the situation can be changed, the smart thing to do is to give this man some other kind of work, in which he will be interested and become a more careful workman. A nervous or high-strung man should not be put on a job where he feels that he is in danger, as he might be if he were required to use a power saw, to handle dynamite or to run a punch press. Just as surely as your safety program fails to take such situations into account, just so surely will you have injured workmen. It is highly necessary to match the workman to the job in the first place and to check each man's actions frequently, in order to be sure that he is doing nothing that he is not supposed to do.

My remarks would be incomplete, if I made no reference to pre-placement physical examinations. The idea of examining men by a capable physician is definitely not to give you an excuse for turning down a job applicant but it definitely is to find out what conditions there are in that man's body that might develop very seriously, if you put him on a heavy-lifting job, sent him up into high places or put him on a saw. I feel very definitely that pre-placement physical examination is an accident-saver and a life-saver, and I personally would not hesitate one minute to hire a man with a double hernia, if I could give him a light job, one at which he could sit down and not have to do any heavy lifting or straining. I would not hesitate one minute to hire a man with one eye for a job that did not require two good eyes or involve any heavy eye strain. There are many men working in our factories today, who are blind or have artificial limbs, and they sometimes prove themselves better workmen than their more fortunate brothers.

To come back a minute to the foreman's responsibility, I recently

investigated a saw-mill accident which involved a trimming saw, on which a 19-year-old lad was squaring off a 14-ft plank. The lad was very much interested in his job, from what I heard—so much so that he constantly was keeping a large supply of trimmed planks ahead of the planer man who was working with him, in order that there would not be any hold-up on the job. In pushing his cut stock away from the saw table he leaned too far over the saw arbor, so that his shirt caught, pulling him on to the 22-in. blade, and he died instantly. That accident was not due to any carelessness on the part of the boy, who was definitely trying to do the best job he knew how. I think the responsibility was far more that of the mill superintendent and the foreman, both of whom had probably seen the lad actually do the same thing that caused his death and did not analyze the situation far enough to become aware of what might happen some day. Surely some additional protection could have been put in front of that trim-saw, to keep the operator at a safe distance from the saw arbor, but there are definite hazards in saw-mill work, as a result of which men have to take some chances, and unconsciously they do a lot of things which could be done in another way to better advantage and more safely. I think this is true in the case I mention and I feel that the lad would be working today, had the mill superintendent not only explained the dangers of the job to him but checked up every once-in-a-while, to see that he was doing his work as instructed. We are all apt to take chances in our every-day life, whether driving an automobile, using a buzz-saw, handling dynamite or digging ditches—particularly after an accident-free period—and we need somebody to check our actions and suggest correction where necessary.

The average workman, as well as the average man or woman, whether working or just living the life of Riley, is too little interested in his or her own safety. You have seen men—and I have, too—working in the bottom of a 6-foot trench just after a heavy rainstorm, without the least thought of a cave-in or maybe feeling that they can get out in a hurry, if they notice that the ground is beginning to slide. I saw them, down at Camp Edwards, laying pipe in 4-foot trenches and in dry sandy soil, and every once-in-a-while a man was caught in a slide before he could get out. I feel that a safety-minded

foreman will not tolerate such work, particularly if he knows that the superintendent's eye is on him and that he will be held definitely responsible for anyone who gets caught in a landslide.

I shudder when I watch street-department men take up a bit of paving and break the surface with a sledge-hammer and bull-point. One man on his haunches holds the bull-point and the other chap swings the sledge-hammer, never thinking of the flying chips that might, and actually do occasionally, destroy an eye, and the foreman's usual alibi is that the men won't wear goggles. I feel that the trouble isn't with the foreman but with the higher-ups, because they don't insist. The foreman may be interested but he can get nowhere without the actual backing, as well as the interest, of the superintendent and the man in the front office. Surely it is hard to get men to wear goggles but the foreman who wears a pair of goggles himself often finds less objection on the part of the men, especially if the men notice that the general superintendent has on a pair of glasses that won't break, if he drops them on the concrete pavement.

In studying your accidents do not be confused between the accidents and the injuries. You should study the accident cause and let the doctor take care of the injury. Study all the facts leading up to the accident, for the sole purpose of finding out what can be done to prevent someone else from being injured in the same way. I can suggest no better method than the procedure found so effective during the last war in training men for new work. In the first place, you must get all of the facts and, when I say "all," I mean every single incident that has any bearing at all on the way the man was injured. If it is an eye case you are looking into, naturally you want to find out whether he was wearing goggles at the time he was hurt. Would he have been injured, if he had had goggles on, or did the goggles fit so loosely that they did not give him full protection? If he wasn't wearing the goggles, why wasn't he wearing them? Were they properly fitted to his face? Were they the proper type of goggles? Ii he wore them occasionally, what was his reason for not having them on when the injury occurred, etc., etc. Get all of the facts and, after you have them all down on paper, it might be well to find out something about the man himself, about his traits, about his habits, about his own eye condition, for it may be that he needed corrective

glasses. About now you have come to the time when you have to weigh the facts and decide what you are going to do, to determine what steps can be taken to prevent somebody else from receiving an injury under similar conditions, but I warn you that it is absolutely fatal to the success of your safety program, if you allow yourself to think for one second that there are those so-called "unpreventable accidents", "just a case of pure carelessness".

Assuming that you have all the facts and have studied them carefully and feel you are ready to take action, I suggest that you call some of your key men—your superintendent and perhaps one or two of your best foremen—together and show them how thoroughly you are going into this job of keeping the men from being injured. Naturally, it is their advice and suggestions that you want to get and I have yet to find a group of superintendents and foremen, who, properly approached, don't have a lot of very valuable and helpful ideas, that can be put into effect and ultimately make job operations safer.

It may be that you will find one of your foremen has all the accidents and this little conference I mentioned above is just the right place to do a safety-selling job on this particular accident-prone foreman, whom I would not think of firing, provided he is reliable in other ways, until I had made a very decided effort to convert him practically and definitely to the proposition that accidents can be prevented.

Don't try to do the job all alone. Personally, I think it is a big mistake to try and run a safety program among any group of men without the help of one or two key individuals and I so feel principally because it is definitely everybody's job. I believe that there ought to be a definite safety program for every group of individuals on a job, in a plant or connected together in any way and that the program should function with the approval and support of the front office, the superintendent and one or two key individuals on the job who contact the workmen. Frequent and periodic get-togethers of such a group, to review and study the accidents and plan the prevention activities, are to my mind very necessary indeed.

The job superintendent may not feel highly honored by a visit from the chief executive to the job but the foremen and the workmen

do, and I think that it is absolutely necessary that the chief executive conform to all safety rules and regulations of the job, just as the men are required to do. If goggles or a hard hat are indicated on the job, see that you have them on before you go around among the men. In other words, be a safety addict yourself and, while you may criticise the tripod, the feet of which are not properly blocked, be sure that you compliment a safety-minded foreman or the workmen on the job where the tripod legs are securely blocked. A pat on the back for a job well done is always a great deal more effective than a pat lower down and, once your men become thoroughly aware of your safety consciousness and interest in their welfare, you have gone a long way towards building a very desirable safety record.

Make sure that chain-falls, ropes and slings are carefully checked and watched. Excavations do not always need shoring—particularly not if you are cutting through rock—but here is a case where rocks and other materials have got to be kept away from the edge of the trench, so that the men below won't be injured by falling material. You and I have both seen men raise a manhole cover and put down a ladder for one of the workmen to go down to an atmosphere that has not been checked, to find out whether one can breathe or not. Of course, if you haven't provided testing equipment and safety rules don't especially indicate that the air must be checked before a man goes down into a manhole, or if your superintendent does not insist that such safety rules be followed, then I think I am not far wrong when I say that you would be at fault, if anyone were overcome by foul gas in a manhole—and it isn't necessarily foul or poisonous gas, either. I recall a case on record where a workman was actually suffocated in an empty sprinkler tank, into which he went to clean it out. The tank was on a high tower and had a fairly tight roof. The workman descended by means of a ladder through a small opening in the roof and it was found that the man's death was due to lack of oxygen. In getting the facts on a case like this, I would want to know why another workman was not stationed outside of the tank, with a life rope on the one who went inside, as a precautionary measure.

So far, I have talked about injuring your own men, but there is another angle to this safety program and that is the public liability, when you leave an open trench in the street or there is some other

obstruction on the highway. Naturally, red lanterns and horses are indicated at night but, if the job is big enough or located on a busy thoroughfare, a night watchman may even be necessary, to warn people, to keep the lanterns burning and sometimes even to keep the lanterns, because some people have an idea that these red lanterns are public property. If sufficient warning is lacking, whether it be by means of a watchman or a light, and an accident happens, it is often a clear case against you, perhaps paid for by your insurance carrier but nevertheless no credit to your safety record and to your reputation. Serious cases, tried in court, often bring settlements far in excess of policy limits, so there is always the possibility of your department's budget having to stand part of the cost, which a few extra lanterns or the expense of a night watchman might have avoided.

The transportation of workmen is another thing which I feel should be definitely considered from a safety standpoint, because my own records indicate that the transportation of workmen on jobs in open trucks produces some bad injuries. Some of our public-works departments and water departments will, as do our contractors on road jobs, crowd 10 or 15 men into an open truck and send them half a mile down the road. I realize that the men do not want to walk and it would take them too long to walk anyway, but your job is to see that these men sit down in the truck and, if one truck won't hold all the men, use two or three but you insist that the driver insist that the men sit down, before he moves his truck.

In the summer-time you are often troubled with poison-ivy cases. Some people are allergic, while others are not affected, but it is a problem to which different people think they have the solution and yet workmen continue to get poison ivy. Some of our larger contractors use a 7% water solution of photographer's "hypo" and require workmen to bathe their hands, arms and faces frequently, letting it dry on the skin. The solution can actually do no harm but, on the other hand, it does not seem to keep all workmen from contracting ivy poisoning. My advice is that you consult your own physician for advice as to treatment of ivy cases.

A gasoline blow-torch has many uses and usually gets a lot of abuse as well, particularly when thrown in a tool-box with a lot of heavy equipment. Conscientious workmen, who know how to make

a nice solder joint, do sometimes repair—and successfully repair—a leaky torch but my advice to you is in the way of a safety precaution: don't try to mend a leaky torch—scrap it and buy a new one. I have seen the remains of several repaired torches, after they exploded, and the memory of a carefully bandaged individual in a hospital ward leads me to make this recommendation.

There was an article in this morning's paper about two boiler inspectors, who in some way came across a live 13,000-volt circuit and died as a result, and my mind naturally reverts to the common abuse that extension lighting equipment gets on the job. Even 110 volts can kill—potentially all electric circuits should be considered dangerous—and someone should be delegated to check and repair defective extension fixtures frequently, not overlooking the necessity for ground wires and grounding clamps on portable electric tools.

Lastly, I want to say just one word in regard to keeping your first-aid kits on the job. The first-aid kit is necessary but it is useful only in so far as you have an experienced man on the job, who knows how to use what is inside the kit, as well as the simple rudiments of first aid to the injured.

When it comes to blasting operations, it is my theory that some people get so accustomed to handling dynamite and caps that they forget how potent a combination the two can be. It was not so long ago that I could buy dynamite, fuse and caps in most New Hampshire hardware stores and the store clerk would always warn against putting the cap in a pocket that had any metallic substance in it. Things are different today but out on the job one still finds people who would store caps and dynamite together, if not carefully checked by the superintendent, who not only must insist on absolute compliance with state and local regulations but also will follow closely recommendations of the powder manufacturers.

The inspectors and safety engineers who visit your operations can be very helpful, particularly if encouraged to comment to the job foremen and superintendent on practices which they consider unsafe, whether with men, equipment or operating procedure. Therefore my parting advice to you is:

1. Take a lively interest in keeping your men well and safe. Set a good example yourself, by obeying your own safety rules, and

make it a point to know as much about the accident-prevention program as you want your superintendent to know.

2. Insist that your superintendent and foremen regard safe working conditions as part of their operating responsibility and consult with your key men regularly in regard to serious accidents that have happened and plans for their elimination in the future.

3. Get all the facts together concerning your serious accidents before coming to any conclusion as to what action you will take to prevent recurrence.

4. After you have the facts together and have given them serious consideration, take definite action and make sure that your subordinates follow your instructions as to preventive measures that are going to be taken in the future.

COMMUNITY PLANNING

BY FLAVEL SHURTLEFF*

[*Presented March 20, 1947.*]

MR. DORE has made it easy for me by suggesting that I call the signals and let you carry the ball. If you don't get the ball going, I shall be sure that the signals were confusing. Just to keep the ball in an area with which I am acquainted, let me correct the title you have given me. I am not Associate Professor of Planning, Administration and Legislation—three separate and very considerable subjects. I have to do with the rather limited subjects of the administration and legislation of planning. Hence, if you have questions, I hope they may be pointed to this field and not to the field of design.

I have been wondering what would interest you most. Maybe it is the thing in the modern practice of planning which gives it any chance of being called a distinctive science, art or profession. You are probably aware that town planners do not want to be listed as a mere appendage of architecture or engineering. They want to carve out a new science or art.

If you read the planning laws which have been passed in the last 25 years, you will find the words "master plan" prominently connected with most of them. Why the word "master"? Does it mean a plan to be superimposed on all plans? This is a possible interpretation and one that often puts planning on the defensive and brings it into disrepute. Rather in master planning the community is developed as a complete unit, in which all functions and all physical elements are fitted and interrelated as perfectly as possible. Master planning is not street planning, park planning or public building-site location, or even the planning of all public works. And emphatically it is not zoning alone—a common misconception. But it is the planning of all these and other separate divisions of the entire field with the greatest care about their relationships.

Suppose we were given the job of locating new school sites in

*Associate Professor of Administration and Legislation of Planning, Massachusetts Institute of Technology, Cambridge, Mass.

a growing town. If we follow the master-plan concept, we see that the sites are related first of all to school population and to the main arteries of circulation. What a mistake it would be to put our high schools, for instance, on a noisy, heavy-traffic artery!

If modern community planning has any claim to distinction, it is because of this emphasis on relationships. I would not have you think, because of my stress on the physical elements of the community, that other basic considerations are disregarded. How foolish it would be to plan for streets, market places or recreation areas without a study of the town's past and its probable economic future, of what kind of place it is and of what purpose it serves. Is it a place primarily where people live, or where they trade, or where processing goes on? Such considerations will determine many of the physical characteristics. The master-plan report will then be made up not only of maps, sketches, diagrams or lines on the map; but there will be economic and social recommendations, and possible chapters on governmental changes. In other words, we should try to make communities that are convenient, attractive and sound, financially and socially.

All this is quite an undertaking and something should be said on how the planner goes about it. I take it that the method in any planning is a good deal the same. In your work you need to know what the plant must be prepared to do and then you outline the best way of doing it. Thus the town planner is first a fact-finder, concentrating on those facts which most contribute to sound conclusions; then he is an analyst of the facts, and lastly he offers a treatment, or a development program.

A community-development program is in its entirety a land-use program, whether the land affected is public or private, but the various uses are usually handled in the planner's report separately, according to function. There are certainly chapters on circulation, covering streets, transportation routes and all kinds of movement thereon, chapters on parks, playgrounds and open spaces generally, chapters on sites for public buildings, and on the control of private-land use through zoning and subdivision regulations.

Zoning ordinances and their administration leave much to be desired, but the legal principle is well established by court decisions

and hundreds of communities of all types and sizes are profiting by this system of control. Not so much can be said of subdivision regulations. The purpose is to postpone the division of acreage into building lots requiring the installation of utility lines, until the present supply of such connections is fully used. From the community standpoint, it would be ideal to require a certificate of necessity, before lands not now supplied with utilities could be opened for subdivision. The courts are probably not prepared to go that far. However, the right of the community to refuse utility connections, until the subdivision has been approved, may be effective. Most subdividers appreciate the advantages to them of full cooperation with community practice.

The general supervision of planning policy is usually placed in the hands of a new municipal agency, the plan commission, almost everywhere appointed and composed mostly of citizen members. They may be chosen for professional competence or business judgment or they may be picked for no apparent reason. They know little about planning and will get their education from the city engineer, who quite often is *ex-officio* a member of the commission, or from a trained planner who is hired for the special job. This is the combination which has the responsibility for making and administering the master plan. Whether it is made at all and, if so, its quality and effectiveness depend on the public demand. My real message to you, as men who know the value of planning, is to try and make the master or development plan mean something in your community. The plan will work, if the people want it to work.

Discussion

A Member. If the mayor of the city for which you worked insisted that you extend the water mains into every street and road in that city, regardless of how far they were from the center and regardless of how few people lived on them, how would you answer him?

Flavel Shurtleff. I would like to have him indicted. He should be told in the most effective way why his suggestion won't work.

Arthur L. Shaw (Boston, Mass.). I think that the answer

to that might be the cold figures as to what it would cost the taxpayers to do that.

A MEMBER. I do not think he cares.

E. SHERMAN CHASE (Boston, Mass.). I have no doubt, Professor Shurtleff, you can give plenty of horrible examples. I wonder if you can give one good example.

PROF. SHURTLEFF. There are many plan commissions working well, carrying out their assignment as makers and administrators of master plans. For large cities I would cite Cincinnati; for the community of 50,000, Montclair, N. J.; for a small town, Winchester, Mass. The essentials—a good plan, competent direction, an understanding public—are all present in these places in good measure and can doubtless be found in many other communities.

FORESTRY OPERATIONS OF THE NEW HAVEN WATER COMPANY

BY RALPH C. HAWLEY*

[*Read April 17, 1947.*]

The forest properties of the New Haven Water Co. comprise approximately 22,000 acres, surrounding the 17 reservoirs in the company's system. The lands are located east, west and north of New Haven, from 3 to 19 miles distant from the center of the city.

At the present time the forest consists of the following:

	%
Conifer plantations	13
Hemlock—hardwood	8
Hardwood	70
Hardwood swamp	9
Total	100

While the New Haven Water Co. was organized in 1849, purchase of land on a large scale did not begin until after 1900. Approximately half of the property has been acquired since 1920.

Since 1907 forestry has been practiced. The purpose has been primarily to develop and maintain the best possible protection to the water supply and secondarily, so far as not incompatible with the primary purpose, to build up an additional source of income from the sale of forest products, provide work projects for permanent company employees in slack periods, and increase the supply of timber available for Connecticut industries.

An early problem was the reforestation of bare lands, particularly those close to reservoirs. These areas were planted to conifers. Approximately 13% of the total area now in forest was planted. This work is now practically completed, with plantations ranging in age from those established recently up to those 40 years old.

Another planting project concerned development of conifer strips

*Professor of Silviculture, Yale University, New Haven, Conn.

between hardwood stands and the reservoirs, to keep hardwood leaves out of the water and reduce maintenance costs.

Experience has shown that, for southern Connecticut, Norway spruce and white pine are the two best conifers to plant for timber production. Thirty to forty miles north of New Haven, where minimum winter temperatures are lower, red pine may be a better tree to plant than the white pine.

If a hardwood is wanted, red oak can be successfully grown by either sowing acorns or setting out seedlings and, on the better soils, yellow poplar can be successfully planted.

Operations in connection with reforestation are:

1. Establishing the plantation.
2. Keeping the planted trees reasonably free of competition.
3. Pruning selected trees.
4. Thinning.
5. Protection against fires, insects and fungi.

Plantations require present investment for future returns and should be made only if (1) protection benefits and reduced maintenance cost justify, or (2) ultimate sales of forest products will pay back investment.

Plantations are not likely to be needed on over 15% of the average watershed area owned, provided land ownership is extended beyond narrow strips alongside reservoirs. Hence, operations in the natural forest covering 85% of the area should in the long run be of greater importance. The New Haven Water Co. has been selling wood and timber since 1907 from these natural forest lands and can do so in increasing volume as the forest grows older.

Much of the land when acquired was stocked with young trees, often less than 10 years of age. Woodland of this age cannot afford profitable cutting for two or three decades and cannot furnish much saw timber until it reaches 60 years of age. The relatively young age of most of the forest land in southern New England explains why financial returns from the sale of forest products seem low in the early stages of forestry practice.

The general principle followed in managing the natural forest has been to cut only if the operation will pay an immediate excess of receipts over expenditures. Exceptions have been made, where it was desired to find temporary work for permanent employees.

Thinning is the chief operation employed. Such cuttings remove only part of the trees on an area, usually about one-third of the total volume, leaving the better-formed individuals of the best species. There should be enough trees left so that, within five to ten years, the crowns of the remaining trees close over the openings made by the thinning.

In the older stands, those 60 to 80 years of age, harvesting of mature timber is underway. Various methods of doing this are employed, depending upon the character and condition of the stand. Sometimes the entire stand is clear-cut over small areas, such as 1 to 10 acres. Usually about 1/3 to 2/3 of the saw-timber volume per acre is removed, the balance being left to furnish seed for a new crop and to maintain a good protective cover on the area.

The method of selling timber used here has varied but has been chiefly "on the stump." Fuel wood has usually been cut before selling.

What kind of forest would be ideal from the water-supply standpoint, to give best water yields of good-quality water and keep maintenance charges on the watershed low? This ideal will vary somewhat for different parts of New England. For Connecticut the ideal would be a forest:

1. Composed of hardwoods with some hemlock or pine in the mixture;
2. Thinned at frequent intervals;
3. With the brush and litter left on the ground to form a mulch;
4. With a belt of conifers along the lakes, extending right down to the water's edge, with live branches left way down to the ground.

Finally, forestry, where undertaken by a water board or company in New England, can and should be a business proposition, ultimately returning an annual net income. To accomplish this, operations which have solely an ornamental, aesthetic or other special purpose must be clearly separated from forestry operations. The latter should be so planned and conducted that they either return an immediate profit on the expenditures or else are of such character (like a well-conceived plantation) that the initial investment ultimately returns a profit.

For the returns to be expected, see "Evaluation of Returns from Forest Lands" (Jour. Am. Water Works Assn., 38: 10, 1105, October, 1946).

WATER SUPPLY FOR THE AIR TRANSPORT COMMAND

BY FRED E. SMITH*

[*Read May 22, 1947.*]

THE purpose of this article is to describe some of the problems encountered in the provision and maintenance of water supply for the Air Transport Command.

The writer was assigned as Medical Inspector of the European Wing—later Division—of the Air Transport Command in May, 1944. Twenty-seven months were served overseas in this assignment, the principal duties being supervision of all phases of environmental sanitation. These included water supply, sewage disposal, mess halls, barracks, and insect and rodent control, together with special investigations at bases of the European Division.

Establishment of ATC bases in theaters of operations depended upon many factors, one of the most important being the element of time. Speed of action was a basic requirement, and the selection of bases was often influenced by the current military situation. These conditions in turn necessitated close coördination of efforts of the engineering section and the medical department in provision of water supply. In instances of rehabilitation of captured bases, which had experienced heavy damage by bombing, joint action by engineering and medical-department staffs was extremely important. Rehabilitation of certain bases, destroyed by American bombing or by enemy demolition prior to evacuation, will be described later.

European Division

The European Wing was established at a single base in the United Kingdom in 1943. The Wing established several additional bases and was made a Division in 1944. After invasion of the continent and the liberation of Paris, expansion of the Division to the continent occurred. Continued growth followed and on V-E Day bases had been established in most of the countries of Europe, from

*Chemist, Water Department, Cambridge, Mass.

Stockholm in the north to Athens in the south. Transfer of ATC bases in North Africa, Middle East and India to the European Division was done after V-J Day. This huge area was administered from Headquarters in Paris, formerly in London.

General Water-Supply Problems

The procurement of water supply presented an individual problem at each base. Climatic conditions were extremely variable, ranging from the cool Scandinavian countries to the tropics of India and Burma. Water treatment available locally might consist of a modern plant or no protection of any sort might be found. Attitudes of native inhabitants were different in the several countries and continents in which bases were located. Procurement of equipment was a serious problem. In France much equipment was found in German supply dumps. In North Africa and the Middle East, supplies required transportation by boat and many items were transported by air to the bases.

Initial sanitary surveys of water supply were made at each base as soon as possible. As most bases were located adjacent to large cities, the municipal water supply, which, in accordance with Theater policy, was supervised by that organization, could in some instances be used at the airport without further treatment. This procedure greatly simplified the water-supply problem. At bases which had been damaged by bombing or which operated their own water-supply systems, the problem presented greater difficulties. Close liaison was maintained with Theater sections in connection with water supply; local water officials were also contacted and their coöperation was obtained.

Base control of water supply was established after completion of surveys and any necessary repair work. Periodic water analyses were made at Army laboratories, usually at a general hospital. Water-supply control data were forwarded regularly to Division and higher Headquarters.

United Kingdom

The ATC bases in the United Kingdom shared joint occupancy of previously established airports with the Royal Air Force. These bases were located throughout the United Kingdom, extending from

northern Scotland to Cornwall and Ireland. The operation of base utilities, including water supply and treatment, was supervised by the British, the responsible official being called the "Clerk of the Works", a civilian employed by the Air Ministry. Water supplies for the airports were obtained by connections with municipal systems of nearby cities or towns. With one or two exceptions, surface waters were used. These were filtered through pressure units with occasional use of alum as a coagulant. A small dosage of chlorine was applied but residual-chlorine tests of tap water showed very low results; often no residual could be detected. Analytical results were satisfactory, however, as obtained from Army laboratories, and it was apparent that the treatment of these supplies, including chlorination procedure, was adequate. Civilian opposition to increased chlorine dosages was frequently encountered.

France and Belgium

ATC personnel were flown to Orly Field, Paris, within a week after the liberation of that city. Orly Field has an interesting history. It had been used for training by the Lafayette Escadrille during World War I. As a German base during the occupation, the airport had been repeatedly bombed by the U. S. Air Force. Only one small building was undamaged; hangars were wrecked and the airport was well spotted with bomb craters.

Rehabilitation of the airport was started immediately. Bomb craters were filled and runways were repaired. Headquarters for the base was established in the one building that was intact. Another building which had been severely damaged was hurriedly patched, to serve as a mess hall. Nearby school buildings were requisitioned for barracks.

As water mains within the airport had been broken in many places by bombs, a repair project was at once begun. The main feed-line in the street beside the airport fortunately had escaped damage. This line served as a source of supply for an Engineer unit which operated an Army water-point to provide potable water for drinking and cooking. Connections were restored between the main feed-line and the distribution system of the airport, and water was then available to chlorinate and flush new and repaired mains. Speed

was a requirement for this project, because the Engineer troops who operated the water-point were shortly transferred with the advance of the Allied armies. Liberal quantities of calcium hypochlorite were used in main chlorination. This practice aroused violent protests from French civilians employed at the airport. On receipt of satisfactory analytical results of samples from the repaired system and investigation of the source of supply, the water supply for the base was approved.

The source of water supply for Orly Field was the Seine River, filtered by the Choisey Le Roi treatment plant in Paris. River water of high bacterial content is pumped by this plant and treated by double slow-sand filtration after sedimentation. A small amount of chlorine—approximately 0.2 ppm—is added to the effluent and, after a detention period, the small residual is removed. Analyses of base water from this supply always indicated the water to be potable.

It was learned that during the occupation the German army assigned a technician to the plant laboratory. The technician checked routine analyses periodically and this practice constituted the only control exercised by the occupying army. The plant had been bomb-damaged to a minor extent; the remainder of the plant was operating normally. The water supply of the city of Paris had suffered little damage and supplementary treatment of the water used by Army units stationed in the city was not required.

At Marseilles the water-supply problem for the ATC base closely paralleled the situation at Paris. The base was located several miles from the city and the municipal water-supply system extended to the airport. The base had been badly damaged by bombing but the airport distribution system was intact. A sanitary survey indicated that the source of supply was a surface water, which was filtered and chlorinated with extremely small dosage by a small plant about three miles from the base. Initial analyses of tap water showed it to be potable. However, as the base supply was part of the Marseilles municipal system, Theater approval of the supply was necessary. In that city many problems and difficulties arose. Dependable plans of the system were not available. The supply—of surface origin—was chlorinated at several points in the system but results of residual-chlorine tests were erratic. Frequent unsatisfactory analyses were

recorded. Periodic shut-downs occurred, usually without prior warning. For these reasons, approval of the entire municipal supply was withheld by the Theater and supplementary treatment with chlorine prior to use was ordered. This order was also directive on the base supply.

The base was equipped with Lister bags for drinking water. To provide potable tap-water for the mess hall and dispensary, a small elevated tank was connected with the two buildings. The tank was provided with a small chlorinator, which was operated by two Italian prisoners-of-war. Results of this arrangement were satisfactory and the treated water eliminated the use of Lister bags in these two buildings.

The original base at Brussels was located about 20 miles from the city. The base was severely damaged and buildings left intact had been stripped of all interior piping. Due to broken water mains, it was necessary to transport water in trucks from a nearby town. The water was then chlorinated in Lister bags. This practice was continued for the short period of ATC occupancy of this base. Removal to another base in Brussels was effected as soon as possible.

Italy

Early in 1945 established bases at Rome and Naples were transferred to the European Division. The base at Rome was several miles distant from the city and the water supply was obtained from the system of a small village located nearby. Source of supply was ground water from springs in hills near the base. A serious supply problem existed, which was an example of history repeating itself. Water shortage existed at the base, similar to conditions which prevailed in ancient times, when aqueducts—ruins of which can still be seen—frequently provided insufficient water for the city of Rome. The base supply was inadequate and the situation was made more difficult by the use of the village supply for irrigation purposes. This condition resulted in frequent and unannounced periods of no water on the base.

The original source of supply could not be enlarged and considerable difficulty arose in attempting to devise a system of allotment or rationing of water to base, village and farmers. Final solution was

effected by procurement of a new and adequate supply. Again springs were utilized as source of supply and chlorination comprised the water treatment. Water analyses were satisfactory. An emergency connection was maintained under appropriate conditions with the old system.

At Naples the base was located on the city boundary. It had not been heavily damaged and municipal utilities, including water supply, were used. The original source was ground water from collecting galleries and local officials chlorinated the water, using Army materials. Even in summer the temperature of the water was very low.

An interesting incident of a Naples Red Cross tour to the ruins of Pompeii was the opportunity to examine lead pipe, still installed in excavated houses of that buried city.

Germany

After V-E Day, bases were established in Germany at Berlin, Frankfurt, Bremen and Munich. In Berlin the base was located at Templehof Airdrome, which maintained its own water supply. It consisted of deep driven wells, with chlorination as the only treatment. At Frankfurt and Munich the airports were several miles distant from the cities and used local water supplies. These were ground waters, chlorinated, and the quality was satisfactory. Extensive pipe repairs were necessary at the base near Frankfurt, where considerable damage to buildings had been done by bombing. The damage to airports, however, was extremely small, when compared to the devastation laid upon the German cities.

It was interesting to learn that some German cities did not routinely chlorinate their water supplies. Munich, for instance, using a water supply from collecting galleries, did not chlorinate the water, probably on the basis of long periods of satisfactory analyses. In the use of water from the Weser River, Bremen filtered and chlorinated the supply. A supplementary surface supply from an upland source did not, however, receive chlorination.

Scandinavia

ATC bases in Copenhagen and Stockholm were adjacent to city limits and were provided with municipal water supply. Copenhagen

uses ground water, part of the supply being treated for iron removal. No chlorination is done. Stockholm has modern purification plants. The source of supply is surface waters and the principal problem is the removal of odor and taste, caused by algal growths. One Stockholm plant uses both rapid- and slow-sand filtration to combat the problem. Obviously both supplies produce water of excellent quality.

Inspections of bases in Denmark and Sweden were most desirable assignments, because of the excellent food available, the fresh milk and the cordial welcome accorded all U. S. Army personnel.

North Africa

Original construction of ATC bases in North Africa was accomplished by another Division. When this area was transferred to the jurisdiction of the European Division, construction was completed and supervisory action only was necessary. At Casablanca the base used the city supply, which was chlorinated at the airport. Wells provided a supplementary supply, which was operated by the base. Chlorination was used as treatment.

The base at Tripoli was located several miles from the city on the shore of the Mediterranean Sea. It was the most attractive base in the Division. A deep driven well provided ample water of excellent quality.

Near Tripoli there is considerable irrigation farming. Water is obtained from dug wells and the procedure of raising the water is interesting. A large bucket or container, made of skins, is lowered into the well. When filled, the bucket is raised by a bullock with a rope harness to a height where a trip mechanism empties the water into a trough. The bullock then returns to the well, the bucket is lowered to be refilled, and the cycle is repeated. The bullock continues this age-old practice without guidance—a method unchanged through the centuries.

Payne Field at Cairo had a complete purification plant. The source of supply was a canal tributary to the Nile. The water was coagulated with alum added to the pump suction. Mixing, sedimentation, rapid-sand filtration and chlorination comprised the treatment process. Wells are provided for emergency use, in the event of failure of the surface supply.

Middle East, India and Siam

The ATC base at Dhahran, Saudi Arabia, recently received publicity in the news-reels and a national magazine. This base is built in the Arabian Desert. All buildings are air-conditioned, to provide endurable working conditions in the high temperature, which often exceeds 120°. Deep wells are the source of water supply, but the salt content and hardness of the water are so great that water for drinking and cooking is distilled. A complete distillation plant operates 24 hours daily and the water receives a small dose of chlorine in the distribution system as a factor of safety.

ATC bases in Karachi and Calcutta were provided with ground-water supplies, which were chlorinated. In Bangkok, Siam, the base was distant from the city and water supply was obtained from wells. As no treatment was provided, Army personnel chlorinated the water in Lister bags. In the city of Bangkok the municipal supply was used. This water is filtered but it is very turbid. This condition may be caused by inefficient filtration or by accumulation of dirt in the mains. As the water was shut off several hours daily, disturbance of pipe deposits resulted. Army personnel filtered the tap water through pulp discs and chlorinated the supply, prior to use for drinking and cooking

Summary

The results of control of water supply at overseas bases of ATC are reflected in the absence of outbreaks of water-borne disease in the Division. Responsibility for control of water supply included not only ATC personnel, but also the thousands of transients—military and civilian—who were transported on ATC planes. Provision of safe water to be used on the planes was another responsibility.

The extent of the large area comprising the European Division resulted in diversity of water-supply problems at the bases. Except in Italy, provision of an adequate quantity of water was not a problem. As a rule, amicable relations were established with local officials, although differences resulted occasionally with reference to water treatment, especially chlorination, in accordance with Army standards.

As would be surmised, the assignment of Medical Inspector involved considerable traveling, in connection with environmental sanitation at bases. All travel was done in military aircraft under many different conditions. Certain flights will never be forgotten, such as the trip from Athens to Rome, when the airplane—a C-54—circled Mt. Vesuvius, near Naples, and all passengers could look into the steaming crater. Other memorable scenes were the Taj Mahal in Agra and a view of devastated Berlin from the air. The experiences in water-supply work under the conditions outlined in this paper, together with the side-lights of travel involved in accomplishment of the mission, made the assignment of Division Medical Inspector one of the most interesting in the Army.

OZONE TREATMENT FOR THE REMOVAL OF TASTE, ODOR AND COLOR FROM WATER

BY VICTOR HANN*

[*Read May 22, 1947.*]

IT is a curious fact that a treatment method used extensively in Europe for more than 40 years has, until recently, been practically overlooked in the United States.

Ozone treatment of municipal water supplies was introduced in France and Germany before the turn of the century and has developed into a major water-purification method. In France alone more than 100 municipalities use ozone. The new St. Maur plant at Paris has a treatment capacity of 79 mgd.

In Europe, ozone was utilized in the beginning because of its germicidal properties. It was well established before chlorine came into general use and has steadily maintained a favored position, not only because of its excellence as a germicide, but especially because of its ability to improve the taste and appearance of the water.

Ozone is the second most powerful oxidizing agent known. Only elemental fluorine is more powerful. It is this oxidizing ability which makes ozone so useful in water treatment. Compounds that cause taste, odor and color in water are complex organic substances, which can be destroyed by oxidation with a sufficiently powerful oxidant. Chlorine (breakpoint chlorination), chlorine dioxide and potassium permanganate have been used successfully to oxidize compounds causing taste and odor in water. Ozone is more powerful than any of these and will, therefore, oxidize compounds not affected by them.

Ozone is an unstable gas, composed of three atoms of oxygen rather than two, as in ordinary oxygen. Because of its instability, it has not been possible to store it and ship it in cylinders, as is common with other commercial gases. It must be generated near the point of use and utilized as it is generated.

*Chief Engineer, Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

To produce ozone, air (or oxygen) is cleaned, dried and passed through an electric discharge. By the action of the discharge a small percentage of the oxygen of the air is converted into ozone.

The mixture of ozone and air is dispersed into the water to be treated, where the ozone reacts with the taste-, odor- and color-producing substances in the water.

The only materials required to produce ozone are air and electricity but, to accomplish this, a certain amount of equipment is required. Some of the items of equipment are not essential to the process of converting air into ozone but are desirable to enhance the operation of the ozone-generating equipment. These auxiliary items are an air filter to reduce maintenance, an air drier to increase operating efficiency and reduce maintenance, and an air compressor to force the air through the filter, drier and ozonator and disperse it into the tank, where it is mixed with the water to be purified.

The essential piece of equipment is the ozonator, which is primarily a means of producing a special type of electrical discharge, through which the air passes. Because of the corrosive nature of ozonized air and the erosive action of the silent electrical discharge, very few materials will give reliable service when used in the vital parts of an ozonator. For the parts exposed to the action of the discharge, only stainless steels and chemically resistant glasses are entirely satisfactory and economically feasible.

Ozonized air is mixed with the water in a tank by dispersion of the gas through porous stone diffusers. The preferred depth over the diffusers is 16 to 20 ft but more shallow tanks can be used at some loss in efficiency. If the water level in the tank is set at the hydraulic grade, head loss through the tank can be held to a few inches of water.

The dosage is varied to meet flow and pollution conditions, by adjustment of the ozonator voltage or by varying the number of ozonators in service. The latter can be started and stopped at the turn of an electric switch. Treatment control can be obtained by measurement of treatment results (color reduction, odor reduction, etc.) or by measurement of ozone residual, which is very similar to measurement of chlorine residual. Close control is usually not necessary, for over-dosage is self-dissipating in a short time and under-

dosage, while failing to accomplish the full potential of the treatment, will improve quality in proportion to the amount of ozone applied. Tastes and odors are not accentuated by an incorrect dosage, as is often the case with chlorine.

The investment cost for an ozone plant varies widely with individual conditions. The cost for a large plant is relatively lower than that for a small one but it is practicable to install ozone plants of capacities as small as 1 mgd or even less. There is no limit to the maximum size. For rough calculations it can be estimated that the installed cost of an ozone plant will be in the range of $10,000 to $25,000 per mgd of treatment capacity.

The operating cost is almost entirely a charge for electricity and therefore depends on the energy rate and the amount of ozone required for the specific problem. Since the equipment is electrically operated, very little labor is required. It is ordinarily not necessary to increase the existing operating force. With present-day ozone equipment, maintenance and replacement costs are very low.

While operating costs for ozone plants vary with specific problems and local electrical rates, the probable limits of operating cost for taste, odor and color problems are presented in Table 1.

TABLE 1. OPERATING COST OF OZONE TREATMENT
(Electricity @ $.01 per kilowatt-hour)

	Cost range per mil gal
Taste and odor removal only	$1.00-$5.00
Taste, odor and color removal	$2.00-$8.00

To estimate the economic value of ozone treatment for taste, odor and color removal, it is necessary to have some idea of the economic losses incurred by *not* removing the taste, odor and color. Admittedly, placing a dollar value on such losses is difficult. Whipple (1) and Shaw and Chase (2) have studied this problem carefully.

Whipple made an exhaustive study of the economic losses to the consumers brought about by a deficiency in quality of the water. He estimated the number of consumers who objected to various intensities and qualities of odors and computed the economic loss, on the assumption that an objecting consumer would buy bottled water, if he could afford it.

It may be argued that not all objecting consumers will buy bottled water and this is probably true, since the poorer consumer cannot afford it. However, the poorer consumer is as much entitled to good water as the more well-to-do one and it seems fair to figure the economic losses on the basis of supplying him with good water, too.

He found that consumers' objections increased with an increase in odor intensity. Objections were relatively much greater toward strong odors than toward faint ones. He also found that the consumer objection varied appreciably at the same odor intensity for different odor qualities. Faint, grassy, aromatic and fishy odors due to microscopic organisms were objectionable to 20% of the consumers. Faint vegetable odors were objectionable to only 8%.

If the retail price of bottled water is $ .10 a gallon and a consumer buys it, because he objects to tastes and odors in the city supply, he spends $7.00 to $8.00 a year that he otherwise would not spend. If 20% of all consumers object, the average annual expenditure for bottled water will be almost $2.00 per capita. This is a lot of money. It is equivalent to spending more than $50.00 per mil gal for treatment at the water plant. In other words, it would be economically justifiable for a city to spend up to $50.00 per mil gal to remove the tastes and odors from the city supply.

According to Shaw and Chase, the late Morris Knowles estimated several years ago that approximately 20 gal of spring water per capita were purchased annually in Lawrence, Mass., as compared with 2 gal in Boston, due to the unsatisfactory character of the Lawrence supply. At $ .10 a gallon this expenditure for bottled water was equivalent to $2.00 per capita at Lawrence and $ .20 in Boston. Thus, in the case of Lawrence, it can be inferred that it would have been justifiable to spend as much as $50.00 per mil gal to produce water of quality equivalent to that in Boston.

Obviously, water can be treated to remove taste and odor for much less than $50.00 per mil gal. At Philadelphia, where a large ozone plant is under construction, it is expected that the use of ozone for taste and odor control will cost only $3.00 to $4.00 per mil gal, including fixed charges.

Color in water causes economic losses, just as tastes and odors do. Whipple found that consumers object to color in direct proportion

to its intensity and estimated that 20% of all consumers object to a color of 40 ppm. On the same basis as used above, this means that an expenditure of $50.00 per mil gal is justifiable to remove 40 ppm of color. Shaw and Chase estimated the economic loss due to this amount of color as somewhat less but still great enough to justify the expenditure of $20.00 per mil gal. For certain types of industry, economic losses due to color in excess of 10 ppm are sufficient to justify expenditures of more than $50.00 per mil gal for corrective measures.

The cost of ozone treatment to reduce the color from 40 ppm to 10 ppm or less will generally be $5.00 to $10.00 per mil gal, including all charges.

These attempts to evaluate the economic losses due to taste, odor and color in water have been based upon the losses to the individual consumer. No account has been taken of additional losses at bottling and food-processing plants, breweries, laundries, industrial bleaching and dyeing establishments and other industries requiring tasteless, odorless and colorless water. Nor has any attempt been made to gage the loss in tourist and recreational trade, permanent inhabitants or new industries.

Certainly it is economically feasible to remove taste, odor and color from water. It can be done for an expenditure of only a fraction of the economic loss sustained by failure to do so. There are many tried and proven methods of removing taste, odor and color. Ozone treatment is only one of them. But a water department is derelict in its duty, if it continues to put out water of deficient quality, when such deficiency can be remedied at reasonable cost.

As stated above, there are many methods of taste, odor and color reduction. Except for ozone, almost all of these require a filter plant for effective use. Ozone will remove taste, odor and color, whether or not it is combined with filtration. Ozone does not require a filter plant, although treatment can be combined effectively with coagulation and filtration.

Where filter plants are already available, the selection of the proper treatment method for taste and odor or color removal will depend upon the individual circumstances. For instance, for simple or infrequent tastes and odors, powdered activated carbon is cheap and effective.

Where tastes and odors are severe and the water is flashy and difficult to control, ozone is most effective. Being a stronger oxidant than any other used for water treatment, it will destroy taste- and odor-producing compounds not otherwise affected. For extremely difficult odor problems, ozone can be combined effectively with activated-carbon treatment, to produce a better water more economically than with either treatment alone.

Color can be reduced by long storage periods or by coagulation with alum or lime, followed by filtration. Ozone will remove color with or without filtration. Sometimes, where high colors are encountered, it is economical to follow a coagulation treatment with ozonation, to remove the last 20 or 30 ppm of color, which are often difficult or impossible to remove by coagulation.

Ozone alone is a very effective and economical means of removing taste, odor and color from water. It can also be combined with other treatment methods, to improve water quality at reasonable cost. In many cases where ozone is introduced as a part of the water-treatment process, substantial savings in the use of chlorine, alum, carbon, etc., have been experienced.

It is believed that the next few years will see the emergence of ozone as a major treatment method in the United States. The city of Philadelphia has recently contracted for an ozone plant, to treat 36 mgd of raw river water for taste and odor improvement, and other large-size plants are under consideration.

References.

1. Whipple, G. C. "Microscopy of Drinking Water," 4th ed., 1927.
2. Shaw, A. L., and E. S. Chase. "Economics of Water Purification". This Journal, *52*, 131 (1938).

COPPER-SULFATE DISTRIBUTOR

BY SIDNEY S. ANTHONY*

[*Read June 11, 1947.*†]

At more or less frequent intervals during the past five years the supply for the Augusta Water District, Carleton Pond, has become infested with numerous types of algal growths, which have been most bothersome, and various methods of treatment have been tried with unsatisfactory results.

We have used the time-honored process of dragging sacks of crystals behind a small motor-boat at various times and tastes and odors have disappeared—whether as a result of the treatment or because the little devils had lived out their span is unknown.

In the winter, when the pond was frozen over, we at one time injected into the mains at the pumping station, by means of a hypochlorinator, a solution of copper sulfate equal to about 3 lb per mil gal of water. This seemed to help until the ice cleared, when we treated in the usual manner.

The method of dragging bags seemed to me to be rather inefficient, since narrow streaks of water were heavily dosed and there was no way to be sure that the entire surface was treated. The wash from the power propeller did not seem to do it and frequent cross trips over the pond merely double-dosed the intersecting tracks and left squares of untreated water like a checkerboard. Copper sulfate in solution being heavier than water would sink to the bottom in the same checkerboard fashion.

About that time I ran across a paper by Frank E. Hale, dated 1930 and entitled "The Use of Copper Sulfate in Control of Microscopic Organisms", on page 23 of which was a snap-shot of a barge being towed behind a motor-boat and spraying chemicals over a wide area—perhaps 25 ft wide. This set me thinking and I experimented a little bit.

*Superintendent and Engineer, Augusta Water District, 12 Williams St., Augusta, Me.

†At a joint meeting of the New England Water Works Association and the New Hampshire Water Works Association.

We had a work boat, square-ended and about 15 ft long and 4 ft wide, on which could be mounted a 9-hp outboard motor and which would travel nearly 10 miles per hour. I had made a distributor pipe about 12 ft long, made up of short pieces of 2-in. pipe and 2-in. by ½-in. tees with ½-in. nipples in the side outlets. A hose led from this distributor to a 3-in. gasoline ditch pump, with a length of suction hose thrown over the side of the boat and a smaller hose from the suction tee to the bottom of a half-section, galvanized range boiler. A small hose also led from the discharge of the pump to the other end of the range boiler. The procedure was to start the outboard motor and the ditch pump, which delivered part of its water to the boiler and part to the distributor. A man standing beside the boiler scooped copper-sulfate crystals into the boiler and stirred the mixture, which then passed through the pump and to the distributor pipe. The scheme worked pretty well, except for two things: the boat was so small and low in the water that the slightest chop scared the operators to death; and the crystals dissolved too slowly. We tried again with pulverized copper sulfate and the solution rate was satisfactory, but again a slight breeze filled the air with dust and irritated eyes and throats of the operators.

Then we tried a small blower, made up with a gasoline-engine drive, and the powder caked in the hopper or the blower and would blow back or rush out in chunks or not at all. The blower was intended to cover a much larger area of pond surface but wind conditions had to be perfect, which they seldom are when you want them to be. Hence we gave up that idea and went back to the spray method.

We knew that a vessel, large enough to be safe and large enough to carry a good supply of copper sulfate and the necessary equipment, was essential and, therefore, one was designed. Since this was early 1945 and most small boat-yards in Maine were closing down, we had no difficulty in finding a yard willing to do the job. I knew the result that was wanted but I am no yacht designer, and the sketch I took down drew a few laughs and suggested changes. The changes were made, and the vessel was built and equipped as shown in Figures 1 to 5. It is 24 ft long, 8 ft wide and 2 ft deep, with an undercut bow, which I hoped would make it move more easily through the water. It is

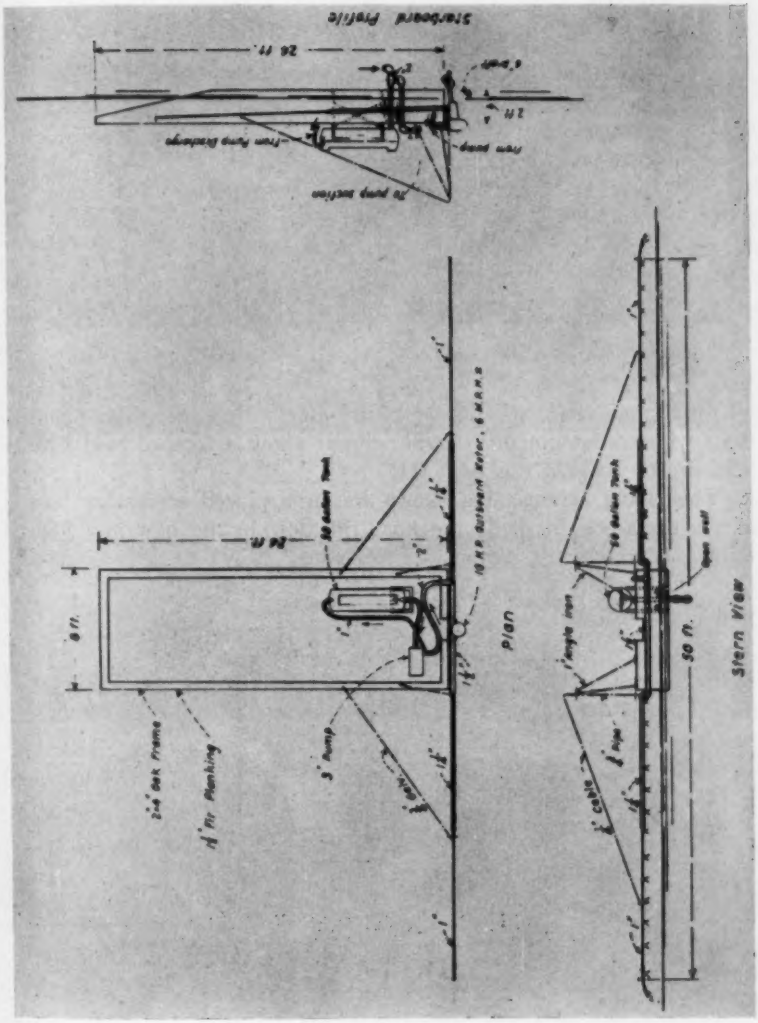

FIG. 1.—SKETCH SHOWING PLAN AND SECTIONS OF COPPER-SULFATE DISTRIBUTOR USED BY AUGUSTA WATER DISTRICT.

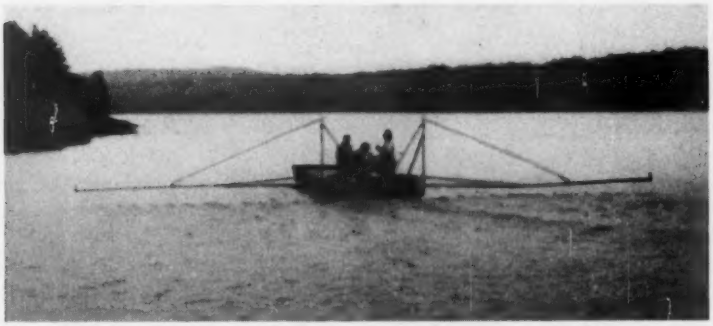

FIG. 2.—VIEW FROM REAR, SHOWING 50-FT SPREAD.

built of fir planking, oak ribs and hard-pine rails and weighs about 2 tons without equipment. It will support about 4 tons of load with 18-in. draft. Its cost was $475.00.

The piping arrangement shown was first placed across the bow but the extra weight made the boat ride low in the bow and high behind. Therefore the piping was shifted to the stern. The original

FIG. 3.—SIDE VIEW OF BOAT, JUST GETTING UNDER WAY, WITH CREW IN OPERATING POSITION.

FIG. 4.—CLOSE-UP OF INTERIOR, ONE MAN RESTING.

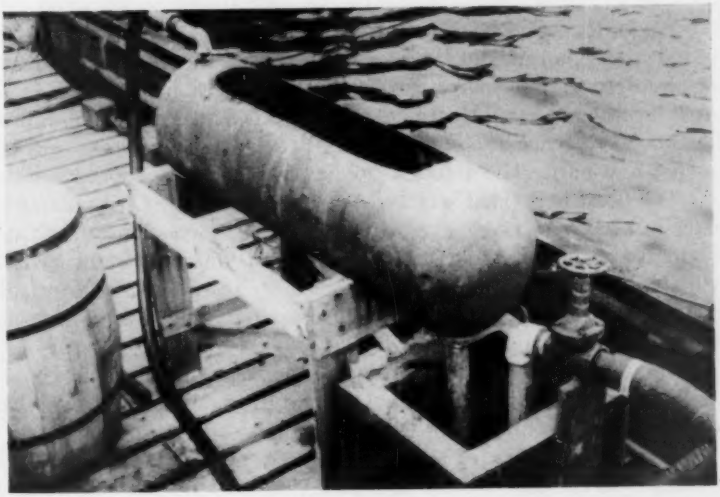

FIG. 5.—VIEW OF MIXING TANK AND WELL.

piping was galvanized iron, which lasted about one season. When used early this year, corrosion had damaged the threads to the point where the piping fell apart. Consequently, the entire equipment has been re-piped with red brass.

Each hose line is valved, so that the flow of water can be diverted to flush various parts of the system, the flow to some parts can be stopped or the scow can be pumped out, when it is filled with rain water.

The pump used is a standard-make, 3-in., self-priming ditch pump, with inlet and outlet reduced to 2-in. The suction and discharge hose is 2-in., wire-wound suction type and the water-supply line to the mixing tank is 1¼-in. high-pressure hose. A short piece of this same hose is used as a suction for pumping out the bilges.

A crew of three men can apply more than 4,000 lb of pulverized copper sulfate per eight-hour day, one man operating the outboard motor, one scooping powder into the tank and the other stirring the mixture. They relieve each other at these jobs, so that there is no monotony.

The helmsman keeps track of the course and sights on a tree or bush on the opposite shore, about 100 ft from the last cross trip in that direction, and then turns for the other shore. After crossing back and forth the course is changed to longitudinal trips. First, however, when starting treatment, two or three trips are made around the shores, to reach the shallows and provide turning areas without missing any part. The solution applied is about 1% copper sulfate.

The pond is divided into three parts, according to the volume of water in each part. We have depth soundings, which indicate a total volume of water of about 1,800 mil gal, of which 725 mil gal are available above the intake. Treatment is based on the available water, on the theory that the sinking copper-sulfate solution does its work as it sinks.

Buoys are placed at these third points and sufficient copper sulfate is loaded in the scow to treat one third. When the scow has been emptied, a return is made to the storehouse for another load.

The effectiveness of this method of application was shown drastically in the late summer of 1945. A rapid increase in the number of standard units of algae during late July and early August indicated

that treatment would be required. On V-J Day the treatment was started and it was completed the next day.

From September of 1945 until April of this year, weekly examinations of the water taken from the gate-well showed not more than 10 of any variety of algae present and many of the reports showed a long string of zeros, with notations that "occasional" this or that was present.

In the middle of April, 1947, the counts of *Dinobryon* suddenly shot up to more than 100 standard units for a couple of weeks and then to 250. Therefore, on April 20 and 22, 3,600 lb of copper sulfate were applied. The count still ran high but was slowly diminishing, and on May 12 a second dose was applied. Many dead cells were observed thereafter but live ones were in the minority.

We still are at a loss to understand why, in 1945, a low count of *Synedra* and *Synura* gave rise to many complaints of unpleasant taste and odor, whereas counts of *Dinobryon* as high as 275 standard units produce no discussion of the subject of tastes and odors whatever.

We feel satisfied that we have developed one of the most effective surface treatments for copper sulfate and shall continue to use it as need develops, until someone with a helicopter settles near Augusta and can show us a lower-cost and more effective method of applying this chemical.

WHAT IS A SAFE AND SATISFACTORY WATER FROM A CHEMICAL STANDPOINT?

BY GAIL P. EDWARDS*

[*Received December 6, 1946.*]

FROM a chemical standpoint, a safe and satisfactory water for drinking and culinary purposes should be free from poisonous substances, clear, colorless, odorless and pleasant to the taste and should not contain an excessive amount of soluble mineral substances nor of any chemicals employed in treatment.

The substances which are found in water and commonly considered poisonous or injurious are the salts of the following metals: lead, copper, arsenic, selenium, fluorine and chromium. According to the standards adopted by the United States Public Health Service for drinking and culinary water supplied to common carriers in interstate commerce, lead must not exceed 0.1 ppm, arsenic 0.05 ppm, selenium 0.05 ppm, fluoride 1.5 ppm and hexavalent chromium 0.05 ppm. These standards also require of a water that:

1.	Sulfate (SO_4) should not exceed	250	ppm.
2.	Magnesium (Mg) " " "	125	ppm.
3.	Chloride (Cl) " " "	250	ppm.
4.	Iron (Fe) and Manganese (Mn) together should not exceed	0.3	ppm.
5.	Copper (Cu) " " "	3.0	ppm.
6.	Zinc (Zn) " " "	15.0	ppm.
7.	Phenolic compounds should not exceed	0.001	ppm.

The total solids should not exceed 500 ppm for a water of good chemical quality but, if such a water is not available, a total-solids content of 1000 ppm may be permitted.

For chemically treated waters, the Public Health Service standards specify that the following three requirements should be met:

"(1) The phenolphthalein alkalinity (calculated as $CaCO_3$)

*Chief of Laboratories, Department of Public Works, New York, N. Y.; formerly Laboratory Coördinator, Division of Sanitary Engineering, Massachusetts Department of Public Health.

should not be greater than 15 ppm plus 0.4 times the total alkalinity. This requirement limits the permissible pH to about 10.6 at 25°C.

"(2) The normal carbonate alkalinity should not exceed 120 ppm. Since the normal alkalinity is a function of the hydrogen-ion concentration and the total alkalinity, this requirement may be met by keeping the total alkalinity within the limits suggested below, when the pH of the water is within the range given. These values apply to water at 25°C.

pH range	Limit for total alkalinity (ppm as $CaCO_3$)
8.0 to 9.6	400
9.7	340
9.8	300
9.9	260
10.0	230
10.1	210
10.2	190
10.3	180
10.4	170
10.5 to 10.6	160

"(3) If excess alkalinity is produced by chemical treatment, the total alkalinity should not exceed the hardness by more than 35 ppm (calculated as $CaCO_3$)."

A safe water must, of course, be free from sewage pollution and a sanitary analysis frequently is of assistance in determining the presence of substances which might make the water unsatisfactory as a beverage. These constituents are not usually in themselves harmful but they may indicate conditions or qualities which are undesirable.

The color is due to dissolved or colloidal matter, usually of vegetable origin, and, while it is not usually indicative of pollution, it does make the water unattractive.

A more particular public now demands a water that is without turbidity, color or odor and has a pleasant taste. A water which is not pleasing to the eye or to the palate is often regarded with suspicion by the consumer and, although the water may be safe bacteriologically,

the consumer may prefer to use a supply of doubtful quality but of more attractive appearance and taste.

Although there are only four different tastes—sour, sweet, salt and bitter—many other sensations of taste are observed in water supplies. These are actually odors. Any unpleasant odor, such as that from microscopic organisms, hydrogen sulphide or chlorine, should be eliminated.

Turbidity is usually caused by very finely divided suspended matter; it also is a measure of the attractiveness of water and of the efficiency of filtration.

Hardness is a measure of the soap-consuming power of the water and, to a certain extent, of its mineral content. In New England, hardness should be less than 50 ppm, if the water is to be considered suitable for domestic and laundry use. Waters may be considered hard if the value is more than 100 ppm. Whether water is hard or soft depends largely upon local opinion; a water considered hard in some localities would undoubtedly be considered soft in others. The alkalinity determination is of particular value in the operation of filtration plants using coagulants. It has little sanitary significance. We may differentiate between bicarbonate, carbonate and hydroxide alkalinity by the proper use of indicators. Whereas the titration of water with a standard acid will measure the total amount of alkalinity present, the pH or hydrogen-ion concentration is an intensity factor, which measures the active alkalinity and acidity of the water, as opposed to the total available or reserve alkalinity. The pH value is of great assistance in controlling the coagulation of water with alum and other coagulants and it is also a measure of corrosive action on metals. Usually, the lower the pH value, the more corrosive the water is, although other factors may be of more importance in determining the activity of the water.

Dissolved oxygen is present in all surface water used as a water supply and it may or may not be found in ground water. It is one of the principal factors in corrosion and its action is accelerated by the presence of carbon dioxide, particularly in soft waters.

The presence of carbon dioxide tends to increase the ability of water to attack metal. Although it is not the direct cause of corrosion, it accelerates corrosive action by decreasing the pH and by dissolving

protective coating from pipes. The amount of carbon dioxide permissible in a water before corrosion may be expected depends upon a number of factors, principally its hardness and alkalinity, and no definite limit can be set.

Although water in nature is never free from chloride, there is hardly a factor in water analysis which is examined more carefully. In most cases, chloride is present as sodium chloride or common salt, washed from the air or soil, or added as one of the constituents of sewage. Salt itself, in the quantity usually found, is not objectionable but, as it is used so commonly in our food, there is always reason for suspecting sewage contamination where the chloride values run high. These chloride values, however, may be misleading, either in districts where deposits of salt are found or close to the sea, where salt water may enter a well. Comparison should be made with a local water of the same general character, known to be pure. The isochlor charts, where available, are valuable. It should be noted that the chlorides are unchanged during the purification or oxidation of organic matters and do not indicate whether the pollution is recent or remote.

Iron is objectionable, if present in quantities of 0.3 ppm or more, because it causes rust or red water, stains utensils or food in cooking, discolors white goods in laundering and stains plumbing fixtures. The iron, particularly in well water, may appear only as a slight turbidity. In its worst form, the red turbidity may make the water unfit for any practical use.

Manganese, which frequently appears with iron, has similar disadvantages and should not be present in a satisfactory water. The limit sometimes set for iron and manganese together is 0.3 ppm.

Since fecal matter consists partially of protein matter which contains nitrogen, it is desirable to follow the progress of nitrogen from the fresh organic material through the successive steps of organic decomposition and inorganic oxidation. We can do this in a measure by determining the total organic nitrogen (Kjeldahl) or albuminoid ammonia, as representing the nitrogenous organic matter, the free ammonia, as representing partially decomposed material, and the nitrites and nitrates, as stages of oxidation of the nitrogen.

Albuminoid ammonia does not exist as such in water but is

the product of the decomposition of organic nitrogenous substances by alkaline permanganate and bears a variable ratio to the total organic nitrogen in polluted water. In slightly polluted waters, the values obtained are related to color and colloidal matter. The albuminoid ammonia is generally considered with the free ammonia and, according to some authorities, their relative proportion is more important than the actual quantities, because, in all sewages and most effluents, the amount of free ammonia greatly exceeds that of the albuminoid ammonia. When waters yield more free ammonia than albuminoid ammonia, the indications are that the water is more or less polluted with sewage, unless both free and albuminoid ammonia are very low.

The presence of nitrites indicates that organic matter in sewage is undergoing active oxidation or nitrification and that the process is not complete. A water containing even a trace of nitrites must be regarded with suspicion, unless some other source is found from which it has more probably been derived. Many waters containing nitrates, if allowed to stand in contact with iron, lead or zinc in pipes or cisterns, act upon the metal, the nitrates being in part reduced to nitrites and ammonia. Unless the presence of an inorganic reducing agent is indicated, nitrites must be attributed to the incomplete oxidation of animal matter and the water must be regarded as dangerous. The absence of nitrites does not indicate that water is safe or satisfactory, since many polluted waters do not contain this substance.

Nitrates may be considered the final step in the oxidation of nitrogenous organic matter. Because of the larger amount of nitrogen present in animal matter and because this material is more easily decomposed, nitrates are more apt to indicate decomposition of animal than of vegetable substances. The presence of nitrates does not mean that the water is safe. Sewage bacteria may easily survive for periods longer than required for the nitrification of nitrogenous material. Nitrates in the water may, of course, be derived from mineral deposits.

According to "Standard Methods of Water Analysis", the oxygen consumed from permanganate by a water that does not contain nitrites, ferrous iron, sulphides or other oxidizable mineral matter is a partial measure of the organic matter in the sample. The proportion

to the total varies greatly and depends upon the chemical composition of the organic matter. Deeply-colored waters, although of good sanitary quality, are sure to give high results. In many cases of this kind, a simple inspection for the measurement of color would give equally valuable information.

There is no reason for believing that organic matter itself, for example, in river water would have any more injurious effect than nitrates or chloride from such matter and, unless it is present in relatively large amounts, it does not affect the quality of the water any more than the chlorides and nitrates do. The presence of a considerable amount of organic material, however, in a raw water, especially if it can be determined that it is of animal origin, is a sign of pollution. The chemist can detect in the water no single constituent which, with certainty, indicates the presence of sewage. Recent or remote pollution may be indicated, when an excessive amount of chloride, nitrate, ammonia and organic matter is found in the water. Unfortunately, nearly all of these substances may come from other, perfectly harmless sources and it is possible for a small amount of sewage to be present without increasing to an appreciable extent the amount of these constituents. Sometimes, waters which, from the results of the chemical analysis, appear to be polluted come from sources which are practically free from any possibility of contamination. Perhaps just as often, waters which, from the chemical analysis, appear to be very pure come from sources which must be condemned, on account of the possibility of pollution.

To sum up this discussion, it should be said that chemical analysis cannot indicate whether a water is absolutely safe for drinking and culinary purposes. It is, however, of great importance when considered along with the bacteriological examination and the sanitary survey. It can be best judged whether a water is safe and satisfactory only after a thorough sanitary survey, a careful bacteriological examination and the chemical analysis. A chemical test has the advantage that it can be carried out quite rapidly, as compared to the bacteriological examination, and its greatest usefulness is probably in the routine control of water-treatment plants.

In the discussion of a satisfactory water its use for industrial purposes cannot be overlooked. When water is used in the manu-

facture of any article of food or drink, bacterial purity is essential and the quantity or character of the saline constituents is of secondary importance.

Water used for the preparation of ice must be free from color and suspended solids and contain no metallic impurities, such as iron and manganese. The total-solid content should be low and the water should be of the same high degree of purity as drinking water.

For making a good-quality paper, the water must be free from color and suspended solids and from every trace of iron and manganese. The total solids should be low.

In the manufacture of artificial silk, a clear water, absolutely free from color, is required.

For tanning purposes, the water should be free from iron and as soft as possible, because iron and hardness form insoluble compounds with the tannins.

A most common use is for boiler waters. In this case, the water should be soft, free from suspended solids and low in total solids and carbon dioxide.

In general, the best water for a public supply is the most suitable one for those manufacturers who require a good water. Manufacturers requiring special characteristics, in most cases, have either their own supply or suitable means of treating the public supply and employ a trained chemist to control the quality of water desired.

DETERMINATION OF ZINC IN WATER, SEWAGE AND INDUSTRIAL WASTES BY MEANS OF DI-BETA-NAPHTHYLTHIOCARBAZONE

BY LAZARUS RUBIN* AND AARON LEVINE†

[*Received June 13, 1947.*]

In the examination of water supplies and wastes for zinc, there has always been a need for a rapid, reliable and simple method for determining small concentrations. The determination of zinc, as outlined in "Standard Methods of Water Analysis" (1), presents many difficulties. The principle of nephelometry is used in this method, which depends on matching the opalescence produced by the precipitation of zinc as zinc sulfide. Nephelometric methods require that the pH, temperature, ion concentration and speed of precipitation be uniform to get reproducible results (2). All this produces a time-consuming method, with difficulty in reading concentrations of less than 0.005 milligram (5 millimicrons) very accurately.

Recently, the use of organic reagents, such as dithizone (3, 4) and di-beta-naphthylthiocarbazone (5), has found great favor in determining zinc in biological materials. Dithizone, however, requires exacting pH conditions and removal of interfering ions with carbamate, the latter reagent usually causing some loss of zinc (5). Cholak *et al* (6) have described a method, in which an aqueous solution of sodium diethyldithiocarbamate is used with a chloroform solution of di-beta-naphthylthiocarbazone as the extraction agent. In this method, the samples are prepared for analysis by digestion and ashing. Unfortunately, when used for determining zinc in water supplies, this method presents the following difficulties from the authors' experience: (a) the method of digestion and ashing is still time-consuming; and (b) the use of reagents for digestion introduces errors and blank readings for zinc often greater than zinc actually present in the sample.

*Chief of Laboratory, Water and Sewage Laboratories, Mass. Department of Public Health, 541 State House, Boston 33, Mass.

†Assistant Chemist, Water and Sewage Laboratories, Mass. Department of Public Health, 541 State House, Boston 33, Mass.

In the method herein described, no time is spent in digesting or ashing the sample. The zinc, in a measured quantity, is extracted by the di-beta-naphthylthiocarbazone reagent and carbamate at a pH of approximately 9.2. The concentration of zinc is then determined colorimetrically, either by visual observation or with a filter photometer or a spectrophotometer. This method has been used successfully in this laboratory for many months. A complete analysis of zinc can be made in as little as 15 minutes.

Apparatus

1. *Squibb separatory funnels*—capacity, 125 ml.
2. *Color-comparison tubes* (Nessler tubes)—capacity 50 ml.
3. *Glass distilling apparatus, Pyrex*—capacity, 1 liter.

Also, if available:

4. *Kahn mechanical shaker,* with adapter for holding 10 separatory funnels, giving about 140 oscillations per minute.
5. *Photelometer, Cenco-Sheard-Sanford,* with 1-cm cells and filters nos. 645P and 525P.

Reagents

All reagents were C. P. with the exception of di-beta-naphthylthiocarbazone.

1. *Water distilled from Pyrex apparatus.*
2. *Citrate buffer reagent*—pH = 9.2. Dissolve 200 grams of ammonium citrate in a small quantity of water, add 90 ml of NH_4OH, and make up to 1 liter. Use 5 ml of this buffer for every 50-ml sample.
3. *NH_4OH.* Dilute 50 ml conc. NH_4OH to 1 liter with metal-free distilled water.
4. *HCl*—N/5. Dilute 16 ml of HCl (sp. gr. = 1.19) to 1 liter with metal-free distilled water.
5. *Di-beta-naphthylthiocarbazone* (designated in this paper as DN solution). Dissolve 200 mg. in 1 liter of C.P. chloroform, which has been redistilled from Pyrex apparatus.
6. *Carbamate solution.* Dissolve 1 gm of sodium diethyldithiocarbamate in 100 ml of metal-free distilled water.
7. *Standard zinc solution*—2.468 gm of $ZnSO_4$ per liter. 1 ml =

1.00 mg Zn. For standards, dilute 5 ml of above to 1 liter. One ml of the resulting solution will equal 0.005 mg. Zn, or 5 micrograms.

The citrate reagent, the NH_4OH, the DN reagent and the carbamate should be kept in a cold, dark place. Under these conditions, the DN will not decompose for at least two months. When freshly prepared, the DN reagent is green. On standing, the chloroform solution of DN will acquire a slight bluish tinge. This in no way affects the accuracy of the determination.

It is advisable to make up the carbamate solution fresh each time, although satisfactory results have been obtained from use of the same solution over a period of one week.

Prior to using the citrate and NH_4OH solutions, shake 100-ml portions of each with 5 ml of the DN reagent and 1 ml of carbamate, to remove metal impurities. If the chloroform layer after shaking remains green, discard this and proceed with the analytical procedure. If, however, the layer is colored blue or some other shade, discard and repeat the extraction process until the chloroform layer remains green. Two shakings usually suffice. Keep in cold, dark place.

Procedure

A. Colorimetric.

Place 50 ml of the sample or an aliquot portion thereof in a Squibb separatory funnel (or, if a very small quantity of zinc is suspected, evaporate 100 ml of sample to 50 ml in a platinum dish). Add 5 ml of citrate buffer, 5 ml of NH_4OH solution, 2 ml of carbamate, and 5 ml of DN reagent. Shake vigorously for two minutes by hand or, preferably, use the Kahn shaking machine. Depending upon the amount of zinc present, the color of the DN-$CHCl_3$ layer will be green through blue, violet and red. Prepare a series of standard zinc solutions by adding 0.0, 0.5, 1.0, 2.0—10 ml of standard zinc solution to 50 ml of water in a Squibb funnel. This corresponds to 0.0 to 1.0 ppm, based on a 50-ml sample, or 0.0, 2.5, 5.0—50 micrograms of zinc. Add the same quantities of reagents as above and shake in the same way. Let stand 10 minutes and compare the resulting colors of the samples with the standards in 50-ml Nessler

tubes. The authors have also been able to obtain good comparisons when viewing the DN layers in the separatory funnels. However, this necessitates separatory funnels of the same size and shape.

Modified Procedure

In the presence of certain interfering ions, the DN-$CHCl_3$ layer may start to fade to a yellowish-brown. If this takes place, transfer this layer to a Squibb funnel, discarding the water layer. Add 5 ml of N/5 HCl and shake for two minutes. During this procedure the DN layer will revert to a green in color. The zinc remains in the aqueous layer, while all interfering ions pass into the $CHCl_3$ layer. Discard the DN layer and wash the aqueous layer twice with 2- to 3-ml portions of $CHCl_3$, also discarding the washings. To the aqueous layer, add 12 ml of NH_4OH, 5 ml of citrate buffer, 15 ml of water, 2 ml of carbamate and 5 ml of DN reagent. Shake for two minutes. Then compare with standards.

B. Photometric.

The same procedure is followed as above. However, the final DN layer, after being shaken, is drawn off into Nessler tubes and diluted with chloroform to the 50-ml mark. The transmittance or density of the resulting solution is determined in the filter photometer or spectrophotometer at 525 or 645 millimicrons. The amount of zinc present is determined from standard curves, obtained by carrying known amounts of zinc through the same steps and plotting the resulting readings of the photometer on semi-logarithmic graph paper (see Figures 1 and 2).

Experimental Findings

1. *Effect of varying quantities of DN reagent and carbamate.*

Two hundred milligrams of DN per liter produced the optimum range of colors for the standards, quantities of zinc from 1 to 50 micrograms being easily read. Quantities of DN smaller and greater than this amount per liter did not produce a range of colors which were easily read.

The use of quantities of carbamate less than those indicated produces colors more on the red side and difficult to discern in the higher ranges, such as 30 to 50 micrograms of zinc.

The use of carbon tetrachloride as a solvent was unsuccessful, since it did not completely dissolve the di-beta-naphthylthiocarbazone.

2. *Interfering cations and anions.*

Known amounts of cations and anions usually found in water were tested, to find their effect on the DN reagent and on the recovery of zinc. Table 1 shows the effect of various cations and anions on the DN reagent, each treated as in "Procedure."

TABLE 1.—EFFECT OF VARIOUS CATIONS AND ANIONS ON DN REAGENT IN DETERMINATION OF ZINC.

Cation	Added (ppm)	Color of DN layer	Remarks
Pb^{++}	10	green	No interference
Cu^{++}	0.30	green	No interference
Cu^{++}	0.50	green	Fades to brownish-yellow in 15 min
Cu^{++}	1.0	green	Fades to brownish-yellow in 15 min
Mn^{++}	0.20	green	No interference
Mn^{++}	0.30	green	Fades to brownish-yellow in 15 min
Fe^{++}	1.0	green	No interference
Fe^{++}	2.0	green	Fades to brownish-yellow in 15 min
Fe^{+++}	2.0	green	No interference
Sn^{++}	2.0	green	No interference
Sn^{++++}	2.0	green	No interference
Al^{+++}	5.0	green	No interference
Mg^{++}	50.	green	No interference
Ca^{++}	50.	green	No interference
Anion			
Cl^-	500	green	No interference
SO_4^{--}	200	green	No interference
NO_3^-	200	green	No interference
HCO_3^-	500	green	No interference
CO_3^{--}	500	green	No interference
PO_4^{---}	25	green	No interference
F^-	10	green	No interference
Calgon	5, 10, 20, 40, 50	green	No interference

From this table it can be seen that copper over 0.50 ppm, manganese over 0.30 ppm, and iron over 2.0 ppm interfere with the color

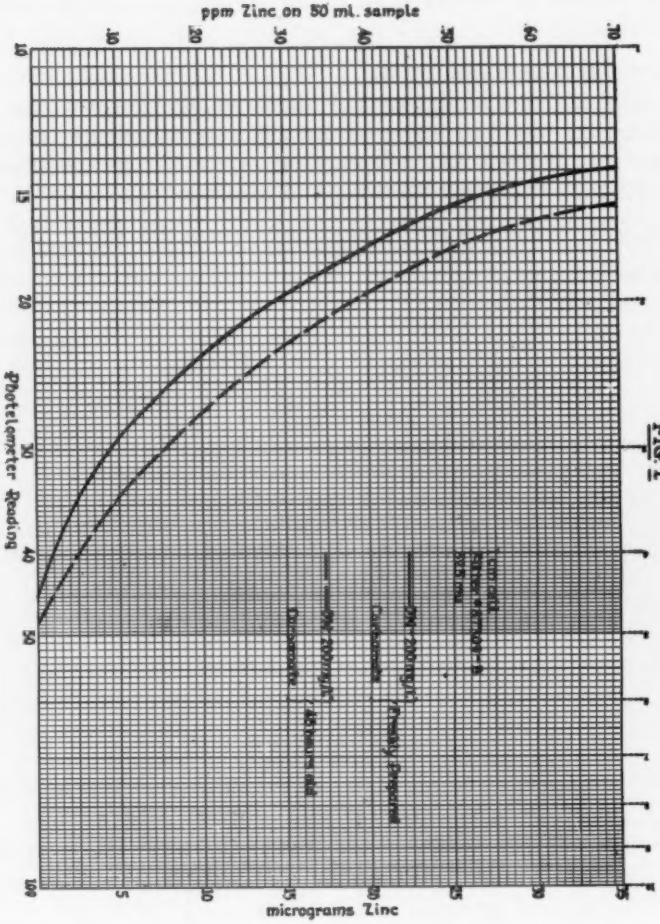
ppm Zinc on 50 ml. sample
Photometer Reading
micrograms Zinc

Fig. 1

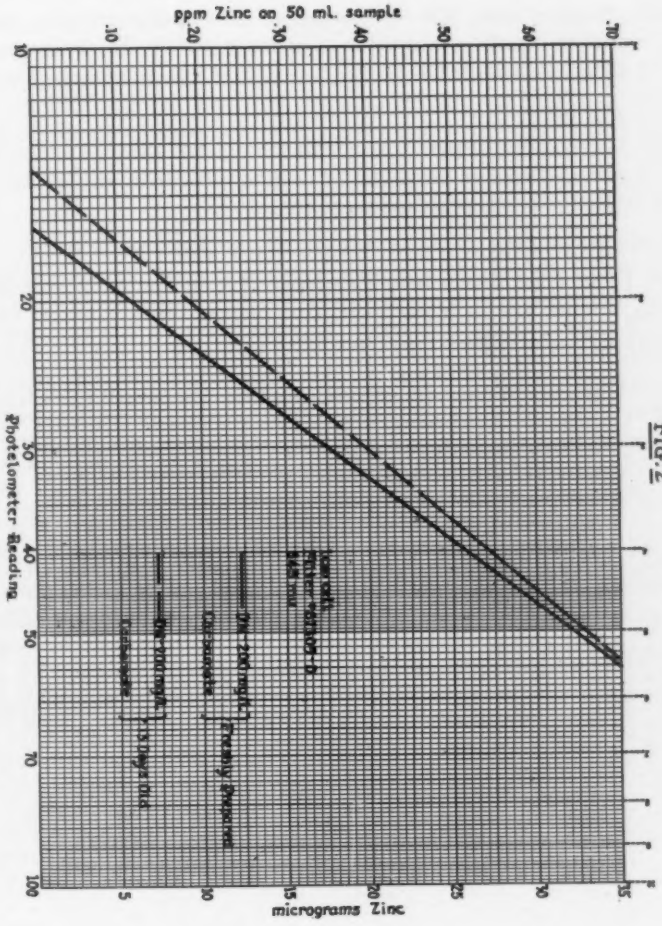
ppm Zinc on 50 ml. sample
10
20
30
40
50
70
Photometer Reading
100
5
10
15
20
25
30
35
micrograms Zinc

Fig. 2

of the DN reagent but only after standing 15 minutes or more. When a 50-ml sample is used, this corresponds to 0.025 milligram of copper, 0.015 mg. of manganese, and 0.1 mg. of ferrous iron. In these cases, the "Modified Procedure" is used.

3. *Effect of pH*

Small variations of pH from 8.8 to 9.6 did not seem to affect the range of mixed colors or the quantity of zinc recovered. In this work, all the samples were kept at a pH of 9.2.

4. *Recovery of Zinc*

In Table 2 are given results of recoveries of zinc from samples, made by adding known amounts of zinc, copper, lead, tin and iron to waters from lakes, reservoirs and wells.

TABLE 2.—RESULTS OF RECOVERIES OF ZINC FROM VARIOUS ARTIFICIAL SAMPLES.

Sample no.	Metal ions added (ppm)					Sample taken (ml)	Zn recovered (ppm)	Error (ppm)
	Zn	Cu	Pb	Sn++	Fe++			
1	0.05				0.30	50	0.06	+0.01
2	0.02				1.0	50	0.02	0.00
3	0.12					50	0.11	—0.01
4	0.15		5.0	2.0		50	0.14	—0.01
5	0.075				0.50	50	0.08	+0.005
6	0.10					50	0.10	0.00
7	2.0	0.40	1.0	0.20		10	2.2	+0.20
9	1.2	0.40	0.25	0.20	1.0	20	1.3	+0.10
10	0.30		0.25		0.30	50	0.28	—0.02
11	0.00	0.40	5.0		0.20	50	0.00	0.00
*12	0.20	0.80	0.25	0.50		50	0.20	0.00
*13	0.15	0.80	2.5	0.50		50	0.16	+0.01
*14	0.50	0.80	1.0	0.50		50	0.48	—0.02
15	0.90		1.0	0.50		50	0.85	—0.05
*16	3.5	1.0	5.0	2.0		10	3.4	—0.10
17	0.03		0.50	0.20		50	0.02	—0.01
10						100	0.31	+0.01
11						200	0.00	0.00
13						200	0.16	+0.01
17						200	0.04	+0.02

Samples marked with an asterisk showed a fading of the DN layer after 15 minutes and were treated with N/5 HCl, etc., for the removal of interfering metals, as outlined in "Modified Procedure." Larger quantities of samples no. 10, 11, 13 and 17 were evaporated down to 50 ml and then the zinc was determined. The results obtained compared favorably with those when a 50-ml sample was taken directly.

Applicability of Method

To test the applicability of this method, various samples from surface waters, ground waters, sewages, samples of water passing through brass pipe, etc., were analyzed. In many cases, iron, copper, manganese and tin were known to be present. Table 3 shows the quantities of zinc found in some of these samples, together with the quantities of other metals. Highly colored surface waters gave no interference. Ground waters, containing iron and manganese, also showed no difficulties due to interference. In samples C, D and E the "Modified Procedure" was used. Sewage samples, analyzed both before and after adding known zinc quantities, gave satisfactory color readings with no interference due to organic matter. Tap waters (L to Z, inclusive), hot and cold, passed through lead-lined pipe, brass pipe and galvanized-iron pipe, were readily analyzed for zinc in the presence of Pb, Cu and Fe ions. Carbonated beverages, in contact with block tin, solder and old block tin, gave the results shown in AA, BB and CC. There was no interference by the Sn ions with the Zn complex in the DN layer.

TABLE 3.—QUANTITIES OF ZINC AND OTHER METALS FOUND IN SAMPLES OF WATER AND SEWAGE.

		Metals found—ppm			
		Pb	Fe	Mn	Cu	Zn
	Surface Waters—Highly Colored					
A	Color = 190 ppm					0.00
B	Color = 140 ppm					0.00
	Well Waters					
C			0.05	0.40		0.00*
D			0.03	0.50		0.00*
E			0.10	1.4		0.10*
F			0.05	0.15		0.00
G			0.75			0.00
	Sewages					
H	Zinc added, 0.40 ppm					0.38
I	" " , 0.10 ppm					0.11
J	" " , 0.25 ppm					0.22
K	" " , none					0.00
	Tap Waters—passed through lead-lined service-pipe and brass pipe in house					
L		0.02				0.05
M		0.20				0.02
N		0.90				1.0
O		0.05				0.15
P		0.05				0.08
Q		0.13				0.80
	Tap Waters—passed through 60 ft of galvanized iron and 40 ft of yellow brass pipe					
R	Cold water—standing sample		4.4		2.5	0.62
S	" " — " "		0.28		0.20	0.30
T	" " — " "		0.15		1.7	0.60
U	" " —running "		0.18		0.03	0.00
V	" " — " "		0.27		0.02	0.05
	Tap Waters—passed through galvanized iron tank and 40 ft of yellow brass pipe					
W	Hot water—standing sample		1.3		1.3	1.3
X	" " — " "		0.60		0.17	1.6
Y	" " —running "		0.50		0.23	0.70
Z	" " — " "		0.55		0.05	0.20
	Carbonated Beverages					
AA	Block tin added overnight Sn = 0.00 ppm	0.00			0.20	0.12
BB	3½ ft solder—half and half— Sn = 0.1 ppm	3.0				0.20
CC	Old block tin added Sn = 5.5 ppm	0.02				0.04

*"Modified Procedure" used.

Experimental Findings with "Photelometer"

As pointed out by Cholak *et al* (6), the two regions best suited for photometric purposes are 550 millimicrons and 650 millimicrons. This laboratory used Cenco filters nos. 87309-B and 87309-D, of 525 and 645 millimicrons, respectively. Figures 1 and 2 show the zinc transmittance readings on a Cenco-Sheard-Sanford "Photelometer" at these wave-lengths for various ppm. It should be noted that, in deriving these curves, freshly-prepared DN reagent and carbamate were used. The use of older reagents will cause a shift in the curve (note dotted lines in Figures 1 and 2). Table 4 gives the results of analyses of zinc samples by means of the "Photelometer."

Table 4.—Results of Analyses for Zinc by Means of "Photelometer".

Sample	Quantity taken (ml)	Reading	Zinc found Micrograms	Ppm
		@ *525 mu.*		
E	25	36.	2.25	0.09
L	100	26.5	7.0	0.07
M	50	38.5	1.0	0.02
N	10	24.	9.0	0.90
O	50	27.5	6.5	0.13
		@ *645 mu.*		
E	25	17.7	2.25	0.09
L	100	20.5	6.0	0.06
M	50	17.	1.0	0.02
N	10	25.4	10.0	1.0
O	50	21.	7.0	0.14

From this table it can be seen that accurate results are obtained at these two wave-lengths. However, for most work the colorimetric method with visual comparison is satisfactory.

Summary and Conclusions

A method has been devised for the direct determination of zinc in water, sewage and wastes, without the time-consuming nephelometric procedure outlined in "Standard Methods of Water Analysis".

The procedure involves the extraction of zinc by a chloroform

solution, containing 200 milligrams per liter of di-beta-naphthylthiocarbazone and a 1% aqueous solution of sodium diethyldithiocarbamate.

Deviations of pH from 8.8 to 9.6 are possible with no effect on the extraction of the zinc.

Interfering metals, such as copper, iron and manganese, can easily be removed and a determination in 15 minutes is thus made possible.

The recoveries of zinc from simulated and actual samples containing zinc are excellent.

LITERATURE

1. Standard Methods of Water Analysis, 9th ed., p. 58 (1946).
2. Fairhall, L. T., and J. R. Richardson. "The Nephelometric Analysis of Zinc". Jour. Am. Chem. Soc., 52, 938 (1930).
3. Cawling, H., and E. J. Miller. Ind. and Eng. Chem., Anal. Ed., 13, 145 (1941).
4. Holland, E. B., and W. S. Ritchie. Jour. Assoc. Official Agr. Chem., 22, 333 (1939).
5. Hubbard, D. M. Ind. and Eng. Chem., Anal. Ed., 12, 768 (1940).
6. Cholak, J., D. M. Hubbard and R. E. Burkey. Ind. and Eng. Chem., Anal. Ed., 15, 754 (1943).

PROCEEDINGS

April 1947 Meeting

New Haven Lawn Club,

New Haven, Conn.

Thursday, April 17, 1947

There was a trip to the New Haven Fire Department Proving Ground, where a demonstration of the latest in fire-fighting methods was held, under the able direction of Chief Paul Heinz.

After the luncheon, served at the New Haven Lawn Club, President Arthur L. Shaw thanked the heads of the municipal departments for their part in the days activities. A short address of welcome was made by Mayor William C. Celentano. A few brief remarks were made by Fire Chief Heinz and by Police Captain T. Dwyer, representing Chief Clark.

A paper on "Forestry Operations of the New Haven Water Company" was read by Professor Ralph C. Hawley of Yale University, New Haven.

A bus trip, to inspect the forestry operations in the Maltby area and the treatment plant at Woodbridge for the West River supply, followed.

May 1947 Meeting
Manchester Country Club
Manchester, N. H.
Thursday, May 22, 1947

President Arthur L. Shaw in the Chair.

Secretary Knox announced the election of the following new members:

Members: John J. Collins, Jr., Chief Chemist, Water Supply Board, Providence, R. I.; Henry A. Galipeau, Superintendent of Water Works, North Adams, Mass.; George E. Keyes, Superintendent, Water Department, Wilbraham, Mass.; Peter Popielarczyk, Installation of Water Systems, New Britain, Conn.; Gordon T. Richardson, City Engineer, Beverly, Mass.; Thomas W. Speight, Jr., Water Superintendent, East Longmeadow, Mass.; Herman E. Warner, President, Workman-Warner Co., Engineers, Essex Junction, Vt.

Corporate: Yarmouth Water Department, Yarmouth, Mass.

Associate: Inertol Co., Inc., Newark, N. J.

An address of welcome was given by Mayor Josephat Benoit.

A paper on "Water Supply for the Air Transport Command" was read by Fred E. Smith, Chemist, Water Department, Cambridge, Mass.

A paper on "The Use of Ozone in Water Treatment" was read by Victor Hann, of Ozone Processes, Inc., Philadelphia, Pa.

MEMOIR OF
PERCY R. SANDERS

Percy R. Sanders died at his home in Concord, N. H., on May 2, 1947. He had just retired as Superintendent of the Concord Water Works, a position he had held for forty years. In fact, he went to work for the Concord Water Works fifty years ago—in 1897—and became Superintendent in 1907. Thus he gave practically his entire adult life to the service of one organization and that utility benefited greatly by his long-continued loyal and efficient service.

Percy Sanders was the dean of water-works operators in New Hampshire, and his experience and knowledge were at the service of the water utilities of the State, by whom he was frequently consulted and to whom he gave his best freely and graciously.

Born at Lanesville, Mass., in 1875, Percy Sanders was the son of Henry L. and Florence (Smith) Sanders. He is survived by his widow, Mrs. Elizabeth (Stevens) Sanders, one son and four daughters.

He had been a member of the New England Water Works Association since November 13, 1907, and was its President in 1923. He was also a charter member of the New Hampshire Water Works Association and its President in 1942.

By his passing the city of Concord, the State of New Hampshire and the associations of which he was a valued member have lost an outstanding citizen and fellow worker; those who knew him well have lost a good friend. This quiet, competent, kindly man will long be missed by all who knew him.

PERCY A. SHAW

SANITARY ENGINEERS FORM INTER-AMERICAN ASSOCIATION

As a result of two, inter-American, regional sanitary-engineering conferences held in 1946 at Rio de Janeiro, Brazil, and Caracas, Venezuela, a new association of sanitary engineering has been formed. More than 400 sanitary engineers, public-health and public-works administrators, chemical and civil engineers, sanitarians and sanitary chemists from the twenty-one American republics gathered at these two meetings, sponsored jointly by the Ministries of Public Health and Public Works of Brazil and Venezuela, the Pan-American Sanitary Bureau and the Institute of Inter-American Affairs.

This association, called "The Inter-American Association of Sanitary Engineering", is established exclusively for scientific and professional purposes and is a non-profit society. The principal objective is to reach, by common agreement, the solution of problems relating to sanitation and the establishment of standards for the uniform and continuous protection of the people of the hemisphere.

The Association will publish a quarterly journal, containing the technical papers presented at the conferences as well as news items and other articles of interest to persons interested in sanitary engineering.

Sanitary engineers and others engaged in allied sanitation activities are invited to become charter members of the Association before the next conference, to be held in one of the countries south of the equator in November, 1947. Chile has been suggested as the location for this first regular conference of the Association.

Membership in this association offers an opportunity to participate in the development of lasting understanding between the Americas, through the common problem of protecting the health of the people, by an exchange of ideas and the association with individuals having problems and objectives similar to those in the United States. Charter membership is now available to those interested by payment of annual dues of $3. Information may be obtained from Homer J. Hayward, U. S. Representative of the Membershio Committee, Inter-American Association of Sanitary Engineering, N.W. Corner 17th and Constitution Avenues, Washington, D.C.

NOTE RELATIVE TO STANDARD SPECIFICATIONS FOR COLD WATER METERS

With this issue of the JOURNAL are reprinted three "Tentative Standard Specifications for Cold Water Meters", distributed by the American Water Works Association and designated as follows:

7 M.2—T—Current Type;
7 M.3—T—Compound Type;
7 M.4—T—Fire Service Type.

Although all three of these specifications are labeled "Tentative," the first two (7 M.2—T and 7 M.3—T) were advanced to "Standard" status by action of the Board of Directors of the American Water Works Association on July 25, 1947. In the future, the "Standard" documents corresponding to these "Tentative" ones will bear the designations "7 M.2" and "7 M.3". No changes were made in the specifications themselves.

7M.2-T

Tentative

STANDARD SPECIFICATIONS

for

COLD WATER METERS—CURRENT TYPE

American Water Works Association

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AMERICAN WATER WORKS ASSOCIATION
500 Fifth Avenue, New York 18, N. Y.

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Tentative
STANDARD SPECIFICATIONS
for
COLD WATER METERS—CURRENT TYPE

These "Tentative Standard Specifications for Cold Water Meters—Current Type" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

American Water Works Association

Approved as Tentative by the Board of Directors of the A.W.W.A. on January 14, 1946

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Second Printing, July 1947

AMERICAN WATER WORKS ASSOCIATION
Incorporated
500 Fifth Avenue, New York 18, N.Y.

Prepared by

Water Works Practice Committee 7M

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H. V. PEDERSEN
GEORGE READ
GEORGE J. ROHAN
GEORGE C. SOPP
L. S. VANCE
W. VICTOR WEIR

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Effective Date: These *"Tentative* Standard Specifications for Cold Water Meters—Current Type" supersede, on *January 1, 1947,* the "Standard Specifications for Displacement, Current, Compound and Fire Service Meters" insofar as that document relates to current type meters. The prior document was adopted by the A.W.W.A., May 24, 1923, and published in the *Manual of Water Works Practice,* p. 707, et seq. The data included in Table 1, Column 2 are as revised January 15, 1947, by action of the A.W.W.A. Board of Directors.

Tentative

Standard Specifications for Cold Water Meters

Current Type

Section 2–1—General

Sec. 2–1.1—Scope

These specifications embrace the various types and classes of cold water current meters for water works consumer service and cover the materials and workmanship employed in their fabrication.

Sec. 2–1.2—Kind and Type

The kinds of meters covered are service meters of the current, velocity or turbine type. These meters register the flow by recording the revolutions of a water impeller or wheel which is set in motion by the force of the flowing water coming in contact with the impeller or wheel blades.

Section 2–2—Capacity, Size and Length

Sec. 2–2.1—Capacity

Capacity or delivery classification shall be the quantity given in Table 1, Column 2, and is determined by the quantity delivered at the permissible maximum loss of head.

Meters shall have a loss of head not exceeding 20 psi., when the rate of flow is that given in Table 1, Column 2.

Sec. 2–2.2—Size

The size of the meter given in Table 1, Column 1, shall be in terms of the nominal size of opening in the inlet and outlet spuds or flanges of the meter.

Sec. 2–2.3—Length

The minimum and maximum overall lengths of the meter, face to face of spuds or flanges, are given in Table 2, Columns 2 and 3. A filler piece can be inserted to increase the length of the shorter meter, if required, but the meter itself must not be shorter than the minimum length given in the table.

Section 2–3—Design

Sec. 2–3.1—Cases

The outer cases shall be of bronze composition or of cast iron protected by a non-corrosive treatment. Castings shall not be repaired, plugged, brazed or "burned in."

All meters shall have cast on them, in raised characters, the size and model. The direction of the flow through the meter shall be properly indicated. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

TABLE 1

Current Meters

(1) Meter Size, *in.*	(2) Safe Maximum Operating Capacity,* *gpm.*	(3) Maximum Loss of Head, *psi.*	(4) Minimum Test Flow, *gpm.*	(5) Normal Test Flow Limits, *gpm.*	(6) Speed of Impeller, *revolutions per cu.ft.*
1½	100	20	7†	12 to 100	75
2	160	20	10†	16 to 170	75
3	350	20	15†	24 to 400	55
4	600	20	20†	40 to 700	15
6	1,400	20	30	80 to 1,600	15
8	2,500	20	50	144 to 2,800	3
10	3,800	20	75	224 to 4,400	3
12	5,800	20	100	320 to 6,400	1.5
16	11,500	20	150	400 to 12,400	0.5

* See note 3a (*re* Excessive Wear).
† See Sec. 2–4.

Sec. 2–3.2—External Bolts

All external bolts and washers shall be of non-ferrous material, or protective treated iron or steel. Nuts shall be of non-ferrous material and be designed for easy removal after having been long in service.

Sec. 2–3.3—Connections

3.3.1—*Connections for 1½- and 2-in. Meters*

Main case connections for 1½- and 2-in meters may be either spuds or flanges, as required.

3.3.1.1—*Spuds.* Spuds shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942).

3.3.1.2—*Flanges.* Flanges shall be faced and drilled and shall be either of the round or oval type, as required. If of the round type, they shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. If of the oval type, the drilling shall be on the horizontal axis, the thickness shall be at least as great as required for round flanges and the diameter of the bolt circle shall be 4 in. for 1½-in. meters and 4½ in. for 2-in. meters. The companion flanges shall be made of cast iron, and shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942). Companion flanges, gaskets, bolts, nuts and washers shall be provided.

3.3.2—*Connections for 3-, 4-, 6-, 8-, 10-, 12- and 16-in. Meters*

Main case connections shall be flanged. Flanges shall be of the round type, faced and drilled, and shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. Companion flanges shall be faced and drilled and they may be standard companion flanges, flange and bell, flange and spigot, or a combination of any. Standard companion flanges shall be tapped 3, 4, 6, 8, 10, 12 and 16 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942). Flange and bell, and flange and spigot connections shall

TABLE 2

Current Meters

(1) Meter Size, *in.*	Meter Length, *in.*		(4) Tail Piece Length, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register	
	(2) Minimum	(3) Maximum		(5) *cu.ft.*	(6) *gal.*	(7) *mil.cu.ft.*	(8) *mil.gal.*
1½	12¾	13	2¾	10	100	10	100
2	15¼	18⅝	3	10	100	10	100
3	20	24		10	100	10	100
4	22	29¼		100	1,000	10	100
6	24	36¾		100	1,000	100	1,000
8	26¾	48¾		1,000	10,000	100	1,000
10	30	60		1,000	10,000	100	1,000
12	36	68		1,000	10,000	1,000	10,000
16	42	42		1,000	10,000	1,000	10,000

be of cast iron and conform to the American Standard cast-iron pit-cast pipe, class 150 (ASA A21.2-1939), *as far as the specifications apply.* Companion flanges, gaskets, bolts, nuts and washers shall be provided.

Sec. 2-3.4—Registers

Registers may be either "round-" or "straight-" reading, indicating in cubic feet or gallons.

3.4.1—*Round-Reading Registers*

The register pinion and spur gears shall be firmly fastened on their spindles, shall fully mesh with each other and run freely, and shall be so constructed that they cannot become unmeshed. The spindle bearings in the top and bottom register plates shall be bushed with hard vulcanized rubber or other non-metallic bushings. These bushings shall have sufficient depth to insure ample spindle bearing and sufficient clearance to allow the spindles to revolve freely; shall be fitted so they will not work loose; shall be removable; and shall be as nearly as possible non-warping, non-shrinking and non-expanding in heat. The register throughout, except for the dial and index hands, shall be plated or given other protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, as given in Columns 6 and 8.

All the index circles, including the initial circle, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point and shall be accurately set and securely held in place.

3.4.2—*Straight-Reading Registers*

The figures on the number wheels shall be large and distinct so that they can be read easily. The register lock and side gears shall be securely fastened to their number wheel discs and hubs. The tumbler pinions shall mesh accurately at the turnover points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame that they cannot get out of

position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip at the turnover point. All parts of the register shall be plated or given a protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, shall be as given in Columns 6 and 8.

There shall be a test index circle which shall be divided into ten equal parts. The hand or pointer shall taper to a sharp point and shall be accurately set and securely held in place.

Sec. 2–3.5—Register Boxes

Register boxes and lids shall be made of bronze composition or of the same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box so that dirt will be prevented from accumulating on the glass. The glass shall be inserted from the inside and shall be securely held in place without the use of putty or pins. All register compartments shall be provided with a water escape hole $\frac{1}{8}$ in. in diameter. When the meter is equipped with a hood, the register box lid may be omitted.

Sec. 2–3.6—Intermediate Gear Trains

Intermediate gear trains may be mounted on the measuring chambers or in the upper main casings. Gear train frames, spindles, gears and pinions shall be made of durable non-ferrous material. Pinions and spur gears shall be firmly fastened, shall fully mesh with each other and shall run freely. The lower end-bearings for pinion and spur gear spindles that revolve shall be fitted with hard vulcanized rubber or other non-metallic bushings fastened in place so they will not fall or work out and they shall be easily removable. Gear trains may be of either the oil-enclosed or open type. If of the oil-enclosed type, the gear trains shall have a separate housing or shall form a housing with the main casings or measuring chamber and shall operate in a suitable lubricant.

Sec. 2–3.7—Measuring Chambers

The measuring chambers or cages for all meters shall be made of bronze or non-ferrous composition and shall be a self-contained unit firmly seated and easily detached and removed from the main case. Chambers with impellers that have revolving spindles shall have long, hard-rubber-bushed, removable bearings for such spindles. Chambers with impellers that revolve around a stationary stem shall contain a rigid, centrally located, stationary stem for suspending the impeller.

Sec. 2–3.8—Impellers

The measuring impellers, wheels or pistons for all meters shall be made of vulcanized hard rubber. The measuring impeller shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball or other suitable bearings. Measuring impellers mounted on spindles shall revolve in hard-rubber-bushed bearings. The measuring impeller, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

The number of impeller revolutions per cubic foot should not exceed the quantities given in Table 1, Column 6.

Sec. 2–3.9—Strainers

Meters may or may not be provided with strainers. Strainers, if provided, shall be rigid, shall be easily removed and shall have an effective straining area as large as practicable and at least double that of the meter main case inlet.

Sec. 2–3.10—Seal Wire Holes

Register box screws and inlet and outlet couplings shall be drilled for seal wire holes. All seal wire holes shall be not less than $\frac{1}{32}$ in. in diameter.

Section 2–4—Registration

The registration on the meter dial shall indicate the quantity recorded to be not less than 97 per cent nor more than 103 per cent of the water actually passed through the meter while it is being tested at any rate of flow within the limits specified in Table 1, Column 5, under "Normal Test Flow Limits." There shall be not less than 95 per cent of the actual flow recorded when a test is made at the rate of flow set forth in Table 1, Column 4, under "Minimum Test Flow."

Current meters in 1½-, 2-, 3- and 4-in. sizes are not recommended for use where minimum rates of flow less than 7, 10, 15 and 20 gpm., respectively, are likely to be encountered.

For 1½- and 2-in. sizes, displacement meters should be used.

For 3- and 4-in. sizes, compound or displacement meters should be used.

Section 2–5—Pressure Test

Meters shall be guaranteed to operate under a working pressure of 150 psi. without leakage or damage to any part.

Section 2–6—Workmanship and Materials

Meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect has developed within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Section 2–7—Rejected Meters

The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

NOTES

These notes are not part of the specifications. They are given only as information concerning the testing and care of meters and important materials used in meter construction. They are not intended to limit in any way the future development of better materials for general use or the use of special metals with specific waters which may require materials of different composition to give service equal to that recorded in normal practice.

(1) *Tests*

Capacity tests are those which test the design of the meter. When a meter of a given design has once been tested for capacity it should not be necessary to test this type of meter again unless a change has been made in the design.

Registration tests are those which test the assembly and workmanship of the meter. Each meter should be tested for registration, as there is no certainty that, because one meter of a given design is within certain limits of accuracy, all meters of this design will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and the purchaser in making registration tests.

All meters should be tested for accuracy of registration within, and as near as practicable to, the low and high rates given under "Normal Test Flow Limits," and occasionally additional tests should be made at one or more intermediate points. A test at the "Minimum Test Flow" should be made on all meters.

A pressure test should be made on each size of meter of a particular design furnished. This pressure is to be 150 psi., and may be obtained by the use of a hand pump or any method available. The meter should be tested for accuracy before and after it has been tested by static pressure to determine whether there has been any distortion that would affect the registration. It is unnecessary to make more than one pressure test on each size of a given design if satisfactory results are obtained. A working pressure test is preferable to a static pressure test.

If the purchaser has no testing equipment, a certificate should be furnished by the manufacturer showing that each meter has been tested for accuracy of registration and that it complies with the specifications and that the size and design comply with the capacity requirements.

(2) *Testing Equipment*

The minimum test equipment is as follows:

(a) A valve on the supply line which would permit the starting and stopping of the flow without appreciable loss of time.

(b) A valve or other suitable device on the discharge line which can provide the rate of flow desired.

(c) Pressure gages on supply and discharge pipes, so that any change in pressure which would affect the rate of flow can be detected. The discharge pipe must be under sufficient head to guarantee a pressure on the outlet of the meter.

(d) A measuring device of either the volumetric or weighing type. The accuracy of the determination of the amount of water discharged should be such as to bring the limit of error within 0.25 per cent. The amount of water passed should be sufficient to cause at least one revolution of the pointer on the initial dial except for the test at the "Minimum Test Flow" rate. The amount passed at the "Minimum Test Flow" rate should be of sufficient quantity to secure a true indication of the accuracy.

(e) Two piezometer rings of exactly the same diameter for capacity tests. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not fewer than four holes shall be provided, drilled in pairs on diameters at right angles to each other. The inlet ring shall be set close to the meter at a distance of eight diameters or more below the nearest upstream stop valve or fitting, and the outlet ring shall be placed at a distance of between eight and ten diameters from the outlet of the meter. The diameter of the rings, the inlet and the outlet pipes shall be the same as the size of the meter to be tested. The rings are to be connected to a mercury U-tube, equipped with an accurate adjustable scale for measuring the difference in mercury level, by rubber or metallic tubing. Provision is to be made for the complete removal of air from the U-tube and tubing connected therewith, and the installation is to be such that air will rise to the air outlets. Where relatively high flows are to be measured, it is necessary to read both sides of the mercury column simultaneously in order to compensate for irregu-

larities in the diamete of the glass U-tube, and to avoid errors du e to fluctuations.

Suitable pressure gages may also be used.

(3) *Care of Meters*

In a current meter the motion of the impeller is transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, as cubic feet or gallons. The gearing serves to translate the motion of the impeller into the unit of measure indicated by the register. The register is at all times a measure of the number of revolutions of the measuring impeller in terms of cubic feet or gallons. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and after proper calibration will continue to register correctly only as long as the impeller continues to make the proper number of cycles for each unit of quantity passed through the meter. If, after calibration, any condition should develop whereby the impeller is compelled to make less than the proper number of cycles per unit of quantity passed through it, the meter will under-register. If the impeller is compelled to make more than the proper number of cycles, the meter will over-register. The proper number of cycles is the number made at the time the meter is calibrated. Under ordinary working conditions, there are a number of factors that may cause under- or over-registration after comparatively short intervals. The more important of these factors which should be guarded against to secure proper registration are:

(a) *Excessive Wear.* Excessive wear of the moving parts of the meter may be caused by improper setting, by over-speeding, or, in general, by the selection of a meter too small for the work required. The effect of excessive wear of the impeller or measuring chamber is slippage and under-registration. Excessive wear of the intermediate gear train may cause binding of the gears or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should be set in a horizontal position and should not be run at destructive speeds. The capacity of the meters given in the specifications represents the maximum rates of flow at which water should be passed through meters for short periods of time or the peak loads which should come upon meters only at long intervals. These rates would be destructive under continuous service. For continuous 24-hour service meters of the current type should not be operated on flows greater than one-third of the capacity of the meter.

(b) *Temperatures.* High temperatures cause expansion of the rubber impellers, which tends to create unusual friction or to bind the impeller in its chamber. The effect is slippage and under-registration, or failure of the meter. Low temperatures have no noticeable effect on the working parts of the meter. Freezing will stop the meter and possibly damage it.

Cold water meters are not affected by temperatures up to about 80°F. In warm climates, where the temperature of the water is likely to go above 80°F., meters with clearances slightly larger than ordinary should be used, and accuracies indicated in specifications must be modified accordingly.

To avoid troubles caused by temperature, meters should be set at locations where they will be protected from heat and frost. At locations where hot water from heating systems may be forced back through the meter, a check valve and pressure and temperature relief valve should be installed on the outlet side of the meter.

(c) *Corrosion.* All the metals used in the construction of a meter are affected by the corrosive action of water. The action is very slow with most potable waters. The result is that parts of the meter are weakened, particularly the teeth of the open intermediate gears, and, with meters that are idle for long intervals, there is a tendency toward binding. Tuberculation of the outer case in meters of the current type may change the normal direction of flow and cause over-registration.

(d) *Material in Suspension.* Foreign material carried in suspension may be deposited and accumulations of deposit always tend to cause over-registration, as any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause over-registration. Such over-registration is not limited.

Meters provided with strainers will retain the larger particles of material in suspension, but the strainer will soon become clogged if the water is not kept reasonably free of suspended matter. Sand is especially destructive and care should be exercised to keep sand from reaching the pipes supplying the meters.

The finer particles of suspended material cannot be prevented from reaching the meter and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

(e) *Periodic Tests.* Meters properly selected as to size and type will give satisfactory service over a long period of time without attention only when operated under ideal conditions. Under ordinary conditions meters must be given some care if they are to function properly. In most cases it is impossible to ascertain, without actual test, whether a meter which has been in service is registering within the required degree of accuracy. Consequently, to insure reliable meter measurements, it is essential that all meters be subjected to periodic tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under *average* conditions the following intervals between tests should not be exceeded:

Meter Size, *in.*	Years Between Tests
1½	4
2	4
3	3
4	2
6	1
8	1
10	1
12	1
16	1

Many state regulatory commissions specify the intervals between tests on both a time and quantity basis.

Meters of the current type used for measuring unfiltered surface waters should be cleaned about once a year, in order that they may be kept in good working condition. When filtered or exceptionally clean water is used, the interval between cleanings may be longer.

Best results will be obtained from current meters if they are calibrated in place, since the accuracy of these meters is affected by changes in the distribution of velocities through the meter. A meter of this type, calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter, may register incorrectly from the start if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on premises this source of error is minimized.

For 3-in. and larger meters the installation of a test tee in the outlet piping makes testing easier and reduces the cost of testing.

(4) *Bronze.* A bronze which is satisfactory for most waters is that of specifications B62–36 of the American Society for Testing Materials or No. 2 Federal Specifications QQ–B–691a for an alloy of copper, tin, lead and zinc, known commercially as composition metal, 85–5–5–5, ounce metal, red brass or hydraulic bronze.

(5) *Rubber.* A satisfactory rubber for impellers and bushings should, among other items, have a specific gravity under 1.2, a minimum tensile strength of 6,500 psi., a maximum elongation of 5 per cent, a hardness (scleroscope test) of not less than 67, a free sulfur content of 3 per cent or less, a free ash content of not more than 3 per cent and a uniformity of cure and physical characteristics.

7M.3-T

Tentative

STANDARD SPECIFICATIONS

for

COLD WATER METERS—COMPOUND TYPE

American Water Works Association

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Tentative

STANDARD SPECIFICATIONS

for

COLD WATER METERS—COMPOUND TYPE

These "Tentative Standard Specifications for Cold Water Meters—Compound Type" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

American Water Works Association

Approved as Tentative by the Board of Directors of the A.W.W.A. on January 14, 1946

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AMERICAN WATER WORKS ASSOCIATION
Incorporated
500 Fifth Avenue, New York 18, N.Y.

Prepared by

Water Works Practice Committee 7M

Personnel

SAMUEL F. NEWKIRK JR., *Chairman*

EDWARD V. BUCHANAN
JAMES G. CARNS JR.
A. P. KURANZ
H. W. NIEMEYER
H. V. PEDERSEN
GEORGE READ
GEORGE J. ROHAN
GEORGE C. SOPP
L. S. VANCE
W. VICTOR WEIR

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Effective Date: These *"Tentative* Standard Specifications for Cold Water Meters—Compound Type" supersede, on *January 1, 1947,* the "Standard Specifications for Displacement, Current, Compound and Fire Service Meters" insofar as that document relates to compound type meters. The prior document was adopted by the A.W.W.A., May 24, 1923, and published in the *Manual of Water Works Practice,* p. 707, et seq.

Tentative

Standard Specifications for Cold Water Meters Compound Type

Section 3–1—General

Sec. 3–1.1—Scope

These specifications embrace the various types and classes of cold water compound meters for water works consumer service and cover the materials and workmanship employed in their fabrication.

Sec. 3–1.2—Kind and Type

The kinds of meters covered are service meters of the compound type, which consist of the combination of a main meter of the current or displacement type for measuring large flows and a small displacement type meter for measuring small flows, in conjunction with an automatic valve mechanism.

Section 3–2—Capacity, Size and Length

Sec. 3–2.1—Capacity

Capacity or delivery classification shall be the quantity given in Table 1, Column 2, and is determined by the quantity delivered at the permissible maximum loss of head.

Meters shall have a loss of head not exceeding 20 psi., when the rate of flow is that given in Table 1, Column 2.

Sec. 3–2.2—Size

The size of the meter given in Table 1, Column 1, shall be in terms of the nominal size of opening in the inlet and outlet spuds or flanges of the meter.

Sec. 3–2.3—Length

The minimum and maximum overall lengths of the meter, face to face of spuds or flanges, are given in Table 2, Columns 2 and 3. A filler piece can be inserted to increase the length of the shorter meter, if required, but the meter itself must not be shorter than the minimum length given in the table.

Section 3–3—Design

Sec. 3–3.1—Cases

The outer cases shall be of bronze composition or of cast iron protected by a non-corrosive treatment. Castings shall not be repaired, plugged, brazed or "burned in."

All meters shall have cast on them, in raised characters, the size and model

TABLE 1

Compound Meters

(1) Meter Size, *in.*	(2) Safe Maximum Operating Capacity,* *gpm.*	(3) Maximum Loss of Head, *psi.*	(4) Minimum Test Flow, *gpm.*	(5) Normal Test Flow Limits, *gpm.*
1½	100	20	½	2 to 100
2	160	20	½	2 to 160
3	320	20	1	4 to 320
4	500	20	1½	6 to 500
6	1,000	20	3	10 to 1,000
8	1,600	20	4	16 to 1,600
10	2,300	20	8	32 to 2,300
12	3,100	20	14	32 to 3,100

* See note 3a (*re* Excessive Wear).

The direction of the flow through the meter shall be properly indicated. Meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

Sec. 3–3.2—External Bolts

All external bolts and washers shall be of non-ferrous material, or protective treated iron or steel. Nuts shall be of non-ferrous material and be designed for easy removal after having been long in service.

Sec. 3–3.3—Connections

3.3.1—*Connections for 1½- and 2-in. Meters*

Main case connections for 1½- and 2-in. meters may be either spuds or flanges, as required.

3.3.1.1—*Spuds.* Spuds shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942).

3.3.1.2—*Flanges.* Flanges shall be faced and drilled and shall be either of the round or oval type, as required If of the round type, they shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. If of the oval type, the drilling shall be on the horizontal axis, the thickness shall be at least as great as required for round flanges and the diameter of the bolt circle shall be 4 in. for 1½-in. meters and 4½ in. for 2-in. meters. The companion flanges shall be made of cast iron and shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942). Companion flanges, gaskets, bolts, nuts and washers shall be provided.

3.3.2—*Connections for 3-, 4-, 6-, 8-, 10- and 12-in. Meters*

Main case connections shall be flanged. Flanges shall be of the round type, faced and drilled, and shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. Companion flanges shall be faced and drilled and they may be standard companion flanges, flange and bell, flange and spigot or a combination of any. Standard companion flanges shall be tapped 3, 4, 6, 8, 10 and 12 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942). Flange and bell, and flange and spigot connections shall be of cast iron and shall conform to the American Standard cast-iron pit-cast pipe, class 150 (ASA A21.2–1939), *as far as the specifications apply.* Companion flanges, gaskets, bolts, nuts and washers shall be provided.

Sec. 3–3.4—Registers

Registers may be either "round-" or "straight-" reading, indicating in cubic feet or gallons.

TABLE 2

Compound Meters—Main Unit

(1) Meter Size, *in.*	Meter Length, *in.*		(4) Tail Piece Length, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register		(9) Speeds, *revolutions per cu.ft.*
	(2) Minimum	(3) Maximum		(5) *cu.ft.*	(6) *gal.*	(7) *mil.cu.ft.*	(8) *mil.gal.*	
1½	18⅛	20⅞	2⅞	10	100	10	100	75
2	13	28½	3	10	100	10	100	75
3	17	37½		10	100	10	100	55
4	20	39½		100	1,000	10	100	15
6	24	51 7/16		100	1,000	100	1,000	15
8	30	60½		1,000	10,000	100	1,000	3
10	36	72½		1,000	10,000	100	1,000	3
12	64½	77		1,000	10,000	1,000	10,000	1.5

3.4.1—*Round-Reading Registers*

The register pinion and spur gears shall be firmly fastened on their spindles, shall fully mesh with each other and run freely, and shall be so constructed that they cannot become unmeshed. The spindle bearings in the top and bottom register plates shall be bushed with hard vulcanized rubber or other non-metallic bushings. These bushings shall have sufficient depth to insure ample spindle bearing and sufficient clearance to allow the spindles to revolve freely; shall be fitted so they will not work loose; shall be removable; and shall be as nearly as possible non-warping, non-shrinking and non-expanding in heat. The register throughout, except for the dial and index hands, shall be plated or given other protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the initial dial and the minimum capacity of the register of the main meter, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, as given in Columns 6 and 8. The maximum indication of the initial dial and the minimum capacity of the register of the bypass meter, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

All the index circles, including the initial circle, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point and shall be accurately set and securely held in place.

3.4.2—*Straight-Reading Registers*

The figures on the number wheels shall be large and distinct so that they can be read easily. The register lock and side gears shall be securely fastened to their number wheel discs and hubs. The tumbler pinions shall mesh accurately at the turnover points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame that they cannot get out of position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip at the turnover point. All parts of the register shall be plated or given a protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the main meter, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, shall be as given in Columns 6 and 8. The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the bypass meter, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

There shall be a test index circle which shall be divided into ten equal parts. The hand or pointer shall taper to a sharp point and shall be accurately set and securely held in place.

Sec. 3–3.5—Register Boxes

Register boxes and lids shall be made of bronze composition or shall be of the same material as the top case, with the name of manufacturer cast on the lids in raised letters. The serial number of the meter shall be plainly stamped on the lids of both the main and bypass meters. If required, the serial number shall also be stamped on the cases. The lids shall be recessed and shall lap over the box so that dirt will be prevented from accumulating on the glass. The glass shall be inserted from the inside and shall be securely held in place without the use of putty or pins. All register compartments shall be provided with a water escape hole $\frac{1}{8}$ in. in diameter. When the meter is equipped with hoods the register box lids may be omitted.

Sec. 3–3.6—Intermediate Gear Trains

Intermediate gear trains may be mounted on the measuring chambers or in the upper main casings. Gear train frames, spindles, gears and pinions shall be made of durable non-ferrous material. Pinions and spur gears shall be firmly fastened, shall fully mesh with each other and shall run freely. The lower end-bearings for pinion and spur gear spindles that revolve shall be fitted with hard vulcanized rubber or other non-metallic bushings fastened in place so they will not fall or work out and they shall be easily removable. Gear trains may be of either the oil-enclosed or open type. If of the oil-enclosed type, the gear trains shall have a separate housing or shall form a housing with the main casings or measuring chamber and shall operate in a suitable lubricant.

Sec. 3–3.7—Measuring Chambers

3.7.1—*Displacement*

The measuring chambers for displacement type meters shall be made of bronze or non-ferrous composition and shall not be cast as part of the outer casings. They shall be machined carefully and secured in position in the outer casings so that any slight distortion of the casings which might occur under 150-lb. pressure will not affect the sensitiveness of the meters.

3.7.2—*Current*

The measuring chambers or cages for current type meters shall be made of bronze or non-ferrous composition and shall be self-contained units firmly seated and easily detached and removed from the main case. Chambers with impellers that have revolving spindles shall have long, hard-rubber-bushed, removable bearings for such spindles. Chambers with impellers that revolve around a stationary stem shall contain a rigid, centrally located, stationary stem for suspending the impeller.

Sec. 3–3.8—Pistons

The measuring pistons of the displacement type meters shall be made of vulcanized hard rubber, shall be smoothly machined, shall be fitted accurately in their measuring chambers and shall operate smoothly and freely. The plates of disc pistons, whether flat or conical, shall have metal reinforcements or shall be equipped with thrust rollers. Disc pistons may be in one piece or the piston plates may be in one piece and the piston balls in two pieces. The piston spindles or shafts shall be securely fastened in the pistons.

The piston reciprocations, rotations, oscillations or nutations per cubic foot shall not exceed the quantities given in Table 3, Column 6.

Sec. 3–3.9—Impellers

Measuring impellers, wheels or pistons of the current type meters shall be made of vulcanized hard rubber. The measuring impeller shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball or other suitable bearings. Measuring impellers mounted on spindles shall revolve in hard-rubber-bushed bearings. The measuring impeller, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

The number of impeller revolutions per cubic foot should not exceed the quantities given in Table 2, Column 9.

Sec. 3–3.10—Automatic Valves

Automatic valves may be of the compound swing or lever type, the vertical lifting type or a type suitable for such purpose.

TABLE 3

Compound Meters—Bypass Unit

(1) Meter Size, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register		(6) Speeds, *revolutions per cu.ft.*
	(2) *cu.ft.*	(3) *gal.*	(4) *mil. cu.ft.*	(5) *mil. gal.*	
$\frac{5}{8}$	1	10	0.1	1	435
$\frac{3}{4}$	1	10	1	10	250
1	10	100	1	10	115
$1\frac{1}{2}$	10	100	10	100	50
2	10	100	10	100	30
3	10	100	10	100	15

Sec. 3–3.11—Strainers

Meters may or may not be provided with strainers. Strainers, if provided, shall be rigid, shall be easily removed and shall have an effective straining area as large as practicable and at least double that of the meter main case inlet.

Sec. 3–3.12—Seal Wire Holes

Register box screws and inlet and outlet couplings shall be drilled for seal wire holes. All seal wire holes shall not be less than $\frac{3}{32}$ in. in diameter.

Section 3–4—Registration

The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent nor more than 103 per cent of the water actually passed through the meter while it is being tested at any rate of flow within the limits specified in Table 1, Column 5, under "Normal Test Flow Limits," except in the registration of flows within the "change-over" from bypass meter to main meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and

at the end of the "change-over" shall not exceed the figures given in the following table.

Size, in.	Rate of Flow, gpm.
1½	20
2	30
3	60
4	100
6	200
8	320
10	460
12	620

The beginning of the "change-over" is when the accuracy of registration falls below 97 per cent, due to the operation of the automatic valve mechanism, and the end of the "change-over" is when the accuracy of registration again reaches 97 per cent.

There shall be not less than 95 per cent of actual flow recorded when a test is made at the rate of flow set forth in Table 1, Column 4, under "Minimum Test Flow."

Section 3–5—Pressure Test

Meters shall be guaranteed to operate under a working pressure of 150 psi. without leakage or damage to any part.

Section 3–6—Workmanship and Materials

Meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect has developed within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Section 3–7—Rejected Meters

The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

NOTES

These notes are not part of the specifications. They are given only as information concerning the testing and care of meters and important materials used in meter construction. They are not intended to limit in any way the future development of better materials for general use or the use of special metals with specific waters which may require materials of different composition to give service equal to that recorded in normal practice.

(1) *Tests*

Capacity tests are those which test the design of the meter. When a meter of a given design has once been tested for capacity it should not be necessary to test this type of meter again unless a change has been made in the design.

Registration tests are those which test the assembly and workmanship of the meter. Each meter should be tested for registration, as there is no certainty that, because one meter of a given design is within certain limits of accuracy, all meters of this design will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and the purchaser in making registration tests.

All meters should be tested for accuracy of registration within, and as near as practicable to, the low and high rates given under "Normal Test Flow Limits," and occasionally additional tests should be made at one or more intermediate points. A test at the "Minimum Test Flow" should be made on all meters.

A pressure test should be made on each size of meter of a particular design furnished. This pressure is to be 150 psi., and may be obtained by the use of a hand pump or any method available. The meter should be tested for accuracy before and after it has been tested by static pressure to determine whether there has been any distortion that would affect the registration. It is unnecessary to make more than one pressure test on each size of a given design if satisfactory results are obtained. A working pressure test is preferable to a static pressure test.

If the purchaser has no testing equipment, a certificate should be furnished by the manufacturer showing that each meter has been tested for accuracy of registration and that it complies with the specifications and that the size and design comply with the capacity requirements.

(2) *Testing Equipment*

The minimum test equipment is as follows:

(a) A valve on the supply line which would permit the starting and stopping of the flow without appreciable loss of time.

(b) A valve or other suitable device on the discharge line which can provide the rate of flow desired.

(c) Pressure gages on supply and discharge pipes, so that any change in pressure which would affect the rate of flow can be detected. The discharge pipe must be under sufficient head to guarantee a pressure on the outlet of the meter.

(d) A measuring device of either the volumetric or weighing type. The accuracy of the determination of the amount of water discharged should be such as to bring the limit of error within 0.25 per cent. The amount of water passed should be sufficient to cause at least one revolution of the pointer on the initial dial except for the test at the "Minimum Test Flow" rate. The amount passed at the "Minimum Test Flow" rate should be of sufficient quantity to secure a true indication of the accuracy.

(e) Two piezometer rings of exactly the same diameter for capacity tests. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not fewer than four holes shall be provided, drilled in pairs on diameters at right angles to each other. The inlet ring shall be set close to the meter at a distance of eight diameters or more below the nearest upstream stop valve or fitting, and the outlet ring shall be placed at a distance of between eight and ten diameters from the outlet of the meter. The diameter of the rings, the inlet and the outlet pipes shall be the same as the size of the meter to be tested. The rings are to be connected to a mercury U-tube, equipped with an accurate adjustable scale for measuring the difference in mercury level, by rubber or metallic tubing. Provision is to be made for the complete removal of air from the U-tube and tubing connected therewith, and the installation is to be such that air will rise to the air outlets. Where relatively high flows are to be measured, it is necessary to read both sides of the mercury column simultaneously in order to compensate for irregularities in the diameter of the glass U-tube and to avoid errors due to fluctuations.

Suitable pressure gages may also be used.

(3) *Care of Meters*

In a compound meter the motions of the pistons and impellers are transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, as cubic feet or gallons. The gearing serves to translate the motion of the pistons and impellers into the unit of measure indicated by the registers. The register is at all times a measure of the number of revolutions of the pistons or measuring impellers in terms of cubic feet or gallons. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and after proper calibration will continue to register correctly only as long as the piston and impeller continue to make the proper number of cycles for each unit of quantity passed through the meter. If, after calibration, any condition should develop whereby the pistons or impellers are compelled to make less than the proper number of cycles per unit of quantity passed through it, the meter will under-register. If the pistons or impellers are compelled to make more than the proper number of cycles, the meter will over-register. The proper number of cycles is the number made at the time the meter is calibrated. Under ordinary working conditions, there are a number of factors that may cause under- or over-registration after comparatively short intervals. The more important of these factors which

should be guarded against to secure proper registration are:

(a) *Excessive Wear.* Excessive wear of the moving parts of the meter may be caused by improper setting, by over-speeding, or, in general, by the selection of a meter too small for the work required. The effect of excessive wear of the pistons, impellers or measuring chambers is slippage and under-registration. Excessive wear of the intermediate gear trains may cause binding of the gears or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should be set in a horizontal position and should not be run at destructive speeds. The capacity of the meters given in the specifications represents the maximum rates of flow at which water should be passed through meters for short periods of time or the peak loads which should come upon meters only at long intervals. These rates would be destructive under continuous service. For continuous 24-hour service meters of the compound type should not be operated on flows greater than one-third of the capacity of the meter. If a compound meter is to be used for continuous service at a more or less uniform rate of flow, care should be taken to select a size of meter in which the "change-over" point is lower than the flow which is usually to be measured.

(b) *Temperatures.* High temperatures cause expansion of the rubber pistons and impellers, which tends to create unusual friction or to bind the piston or impeller in its chamber. The effect is slippage and under-registration, or failure of the meter. Low temperatures have no noticeable effect on the working parts of the meter. Freezing will stop the meter and possibly damage it.

Cold water meters are not affected by temperatures up to about 80°F. In warm climates, where the temperature of the water is likely to go above 80°F., meters with clearances slightly larger than ordinary should be used, and accuracies indicated in the specifications must be modified accordingly.

To avoid troubles caused by temperature, meters should be set at locations where they will be protected from heat and frost. At locations where the hot water from heating systems may be forced back through the meter, a check valve and pressure and temperature relief valve should be installed on the outlet side of the meter.

(c) *Corrosion.* All the metals used in the construction of a meter are affected by the corrosive action of water. The action is very slow with most potable waters. The result is that parts of the meter are weakened, particularly the teeth of the open intermediate gears, and, with meters that are idle for long intervals, there is a tendency toward binding. Tuberculation of the outer case in meters of the current type may change the normal direction of flow and cause over-registration.

(d) *Material in Suspension.* Foreign material carried in suspension has a tendency to fill the space between the piston and measuring chamber and cause over-registration of displacement meters. Such over-registration, however, is limited and cannot generally exceed 3 per cent.

Accumulations of deposit always tend to cause over-registration of current meters, as any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause over-registration. Such over-registration is not limited.

Meters provided with strainers will retain the larger particles of material in suspension, but the strainer will soon become clogged if the water is not kept reasonably free of suspended matter. Sand is especially destructive and care should be exercised to keep sand from reaching the pipes supplying the meters.

The finer particles of suspended material cannot be prevented from reaching the meter and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

(e) *Periodic Tests.* Meters properly selected as to size and type will give satisfactory service over a long period of time without attention only when operated under ideal conditions. Under ordinary conditions meters must be given some care if they are to function properly. In most cases it is impossible to ascertain, without actual test, whether a meter which has been in service is registering within the required degree of accuracy. Consequently, to insure reliable meter measurements, it is essential that all meters be subjected to periodic tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under *average* conditions the following intervals between tests should not be exceeded:

Meter Size, *in.*	Years Between Tests
1½	4
2	4
3	3
4	2
6	1
8	1
10	1
12	1

Many state regulatory commissions specify the intervals between tests on both a time and quantity basis.

Meters of the compound type used for measuring unfiltered surface waters should be cleaned about once a year in order that they may be kept in good working condition. When filtered or exceptionally clean water is used, the intervals between cleanings may be longer.

Best results will be obtained from compound meters if they are calibrated in place, since the accuracy of these meters is affected by changes in the distribution of velocities through the meter. A meter of this type, calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter, may register incorrectly from the start if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on premises this source of error is minimized.

For 3-in. and larger meters the installation of a test tee in the outlet piping makes testing easier and reduces the cost of testing.

(4) *Bronze.* A bronze which is satisfactory for most waters is that of specifications B62–36 of the American Society for Testing Materials or No. 2 Federal Specifications QQ–B–691a for an alloy of copper, tin, lead and zinc, known commercially as composition metal, 85–5–5–5, ounce metal, red brass or hydraulic bronze.

(5) *Rubber.* A satisfactory rubber for pistons, measuring impellers and bushings should, among other items, have a specific gravity under 1.2, a minimum tensile strength of 6,500 psi., a maximum elongation of 5 per cent, a hardness (scleroscope test) of not less than 67, a free sulfur content of 3 per cent or less, a free ash content of not more than 3 per cent and a uniformity of cure and physical characteristics.

Tentative

STANDARD SPECIFICATIONS

for

COLD WATER METERS—FIRE SERVICE TYPE

These "Tentative Standard Specifications for Cold Water Meters—Fire Service Type" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

American Water Works Association

Approved as Tentative by the Board of Directors of the A.W.W.A. on October 24, 1946

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Incorporated

500 Fifth Avenue, New York 18, N.Y.

Prepared by

Water Works Practice Committee 7M

Personnel

SAMUEL F. NEWKIRK JR., *Chairman*

EDWARD V. BUCHANAN
JAMES G. CARNS JR.
A. P. KURANZ
H. W. NIEMEYER
H. V. PEDERSEN
GEORGE READ
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GEORGE C. SOPP
L. S. VANCE
W. VICTOR WEIR

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Effective Date: These *"Tentative* Standard Specifications for Cold Water Meters—Fire Service Type" supersede, on January 1, 1948, the "Standard Specifications for Displacement, Current, Compound and Fire Service Meters" insofar as that document relates to fire service meters. The prior document was adopted by the A.W.W.A. May 24, 1923, and published in the *Manual of Water Works Practice*, p. 707 *et seq.*

Tentative

Standard Specifications for Cold Water Meters Fire Service Type

Section 4–1—General

Sec. 4–1.1—Scope

These specifications embrace the various types and classes of cold water compound meters (fire service type) for water works consumer service, and cover the materials and workmanship employed in their fabrication.

Sec. 4–1.2—Kind and Type

The kinds of meters covered are service meters of the compound type, which consist of the combination of a main meter of the proportional type for measuring large flows and a small displacement type meter for measuring small flows, in conjunction with an automatic valve mechanism. The combination is designed to afford a clear passage through the main meter when its valve is raised from the seat.

Section 4–2—Capacity and Size

Sec. 4–2.1—Capacity

Capacity or delivery classification shall be the quantity given in Table 1, Column 2, and is determined by the quantity delivered at the permissible maximum loss of head.

Meters shall have a loss of head not exceeding 4 psi. when the rate of flow is that given in Table 1, Column 2.

Sec. 4–2.2—Size

The size of the meter given in Table 1, Column 1, shall be in terms of the nominal size of opening in the inlet and outlet flanges of the meter.

Section 4–3—Design

Sec. 4–3.1—Cases

The outer cases shall be of bronze composition or of cast iron protected by a non-corrosive treatment. Castings shall not be repaired, plugged, brazed or "burned in."

All meters shall have cast on them, in raised characters, the size and model. The direction of the flow through the meter shall be properly indicated. Meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

Sec. 4–3.2—External Bolts

All external bolts and washers shall be of non-ferrous material or protective treated iron or steel. Nuts shall be of non-ferrous material and shall be

TABLE 1
Fire Service Meters

(1) Meter Size, *in.*	(2) Safe Maximum Operating Capacity,* *gpm.*	(3) Maximum Loss of Head, *psi.*	(4) Minimum Test Flow, *gpm.*	(5) Normal Test Flow Limits, *gpm.*
3	400	4	2	8 to 400
4	700	4	2	8 to 700
6	1,600	4	4	16 to 1,600
8	2,800	4	7	28 to 2,800
10	4,400	4	12	48 to 4,400
12	6,400	4	12	48 to 6,400

* See Note 3a (re Excessive Wear).

designed for easy removal after having been long in service.

Sec. 4–3.3—Connections

Main case connections shall be flanged. Flanges shall be of the round type, faced and drilled, and shall conform to the American Standard cast-iron pipe flange, class 125, (ASA B16a—1939) for diameter, drilling and thickness. Companion flanges shall be faced and drilled, and they may be standard companion flanges, flange and bell, flange and spigot or combination of any. Standard companion flanges shall be tapped 3, 4, 6, 8, 10 and 12 in., respectively, American Standard internal taper pipe thread (ASA B2.1—1942).

Flange and bell, and flange and spigot connections shall be of cast iron and shall conform to the American Standard cast-iron pit-cast pipe, class 150, (ASA A21.2—1939) *as far as the specifications apply.* Companion flanges, gaskets, bolts, nuts and washers shall be provided.

Sec. 4–3.4—Registers

Registers may be either "round-" or "straight-" reading, indicating in cubic feet or gallons.

3.4.1—*Round-Reading Registers*

The register pinion and spur gears shall be firmly fastened on their spindles, shall fully mesh with each other and run freely and shall be so constructed that they cannot become unmeshed. The spindle bearings in the top and bottom register plates shall be bushed with hard vulcanized rubber or other non-metallic bushings. These bushings shall have sufficient depth to insure ample spindle bearing and sufficient clearance to allow the spindles to revolve freely; shall be fitted so they will not work loose; shall be removable; and shall be as nearly as possible non-warping, non-shrinking and non-expanding in heat. The register throughout, except for the dial and index hands, shall be plated or given other protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the initial dial and the minimum capacity of the register of the main unit, when indicating cubic feet, shall be as given in Table 2, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5. The maximum indication of the initial dial and the minimum capacity of the register of the by-pass

TABLE 2

Fire Service Meters—Main Unit

(1) Meter Size, in.	Maximum Indication of Initial Dial		Minimum Capacity of Register	
	(2) *cu.ft.*	(3) *gal.*	(4) *mil.cu.ft.*	(5) *mil.gal.*
3	100	1,000	10	100
4	100	1,000	10	100
6	100	1,000	100	1,000
8	1,000	10,000	100	1,000
10	1,000	10,000	100	1,000
12	1,000	10,000	1,000	10,000

unit, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

All the index circles, including the initial circle, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point and shall be accurately set and securely held in place.

3.4.2—*Straight-Reading Registers*

The figures on the number wheels shall be large and distinct so that they can be read easily. The register lock and side gears shall be securely fastened to their number wheel discs and hubs. The tumbler pinions shall mesh accurately at the turnover points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame that they cannot get out of position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip at the turnover point. All parts of the register shall be plated or given a protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the main unit, when indicating cubic feet, shall be as given in Table 2, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5. The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the by-pass unit, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

There shall be a test index circle which shall be divided into ten equal parts. The hand or pointer shall taper to a sharp point and shall be accurately set and securely held in place.

Sec. 4–3.5—Register Boxes

Register boxes and lids shall be made of bronze composition or shall be of the same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lids of both the main and by-pass units. If required, the serial number shall also be stamped on

TABLE 3

Fire Service Meters—By-pass Unit

(1) Meter Size, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register	
	(2) *cu.ft.*	(3) *gal.*	(4) *mil.cu.ft.*	(5) *mil.gal.*
1½	10	100	1	10
2	10	100	10	100
3	10	100	10	100
4	100	1,000	100	1,000
6	100	1,000	100	1,000

the cases. The lids shall be recessed and shall lap over the box so that dirt will be prevented from accumulating on the glass. The glass shall be inserted from the inside and shall be securely held in place without the use of putty or pins. All register compartments shall be provided with a water escape hole $\frac{1}{8}$ in. in diameter. Register box screws shall be drilled for seal wire holes not less than $\frac{3}{32}$ in. in diameter. When the meter is equipped with hoods, the register box lids may be omitted.

Sec. 4–3.6—Intermediate Gear Trains

Intermediate gear trains may be mounted on the measuring chambers or in the upper main casings. Gear train frames, spindles, gears and pinions shall be made of durable non-ferrous material. Pinions and spur gears shall be firmly fastened, shall fully mesh with each other and shall run freely. The lower end-bearings for pinion and spur gear spindles that revolve shall be fitted with hard vulcanized rubber or other non-metallic bushings fastened in place so that they will not fall or work out and shall be easily removable. Gear trains may be of either the oil-enclosed or open type. If of the oil-enclosed type, the gear trains shall have a separate housing or shall form a housing with the main casings or measuring chamber and shall operate in a suitable lubricant.

Sec. 4–3.7—Measuring Chambers

3.7.1—*Displacement*

The measuring chambers for displacement type meters shall be made of bronze or non-ferrous composition and shall not be cast as part of the outer casings. They shall be machined carefully and secured in position in the outer casings so that any slight distortion of the casings which might occur under 150-psi. pressure will not affect the sensitiveness of the meters.

3.7.2—*Proportional*

The measuring chambers or cages for proportional type meters shall be made of bronze or non-ferrous composition and shall be self-contained units, firmly seated and easily detached and removed from the main case. Chambers with impellers that have revolving spindles shall have long, hard-rubber-bushed removable bearings for such spindles. Chambers with impellers that revolve around a stationary

stem shall contain a rigid, centrally located, stationary stem for suspending the impeller.

Sec. 4–3.8—Pistons

The measuring pistons of the displacement type meters shall be made of vulcanized hard rubber, shall be smoothly machined, shall be fitted accurately in their measuring chambers and shall operate smoothly and freely. The plates of disc pistons, whether flat or conical, shall have metal reinforcements or shall be equipped with thrust rollers. Disc pistons may be in one piece or the piston plates may be in one piece and the piston balls in two pieces. The piston spindles or shafts shall be securely fastened in the pistons.

Sec. 4–3.9—Impellers

Measuring impellers, wheels or pistons of the proportional type meters shall be made of vulcanized hard rubber. The measuring impeller shall be mounted, or shall rotate on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball or other suitable bearings. Measuring impellers mounted on spindles shall revolve in hard-rubber-bushed bearings. The measuring impeller, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Sec. 4–3.10—Main Controlling Valves

The controlling valve shall be of the mechanical or atmospheric type, in which the initial resistance to opening, for all practical purposes, vanishes after opening. The valve shall cut off all flow through it when the main meter is not in operation, shall effectively prevent backflow and shall not bind or stick in service.

3.10.1—*Mechanical Valves*

The mechanical valve may be of the compound swing or lever type, or of any mechanical type suitable. It shall close by gravity, and the weight of the valve and any supplemental weight imposed on it shall offer sufficient resistance to the incoming water to divert all small rates of flow through the by-pass meter and shall open under a difference of pressure not exceeding 4 psi. When the amount of water being used through the by-pass meter results in a loss in pressure of 4 psi. between inlet and outlet sides of the main meter, the valve shall open and the water passing through the valve shall be recorded on the main meter; and, when the valve is unseated, there shall be a clear passage through the meter. The valve weights shall be of bronze or lead, or of a bronze shell loaded with lead. The valve and supplemental weight pins or spindles shall be of bronze or other suitable non-ferrous material, and all valve and supplemental weight hinge bearings shall be bushed with bronze or hard rubber. If the valve contains a clapper, it shall be faced with semi-hard rubber. Valve seats shall be of bronze, shall have the narrowest satisfactory width of face, shall be screwed into position and shall be equipped with sturdy lugs for easy removal.

3.10.2—*Atmospheric Valves*

The atmospheric valve shall be of the swing type, with an opening between the valve seat and atmosphere so designed that the initial resistance to opening shall not exceed 6 per cent of the pressure on the inlet side. The difference in pressure caused by the atmospheric opening and any supplementary weight imposed on the valve shall hold the valve closed and divert

small rates of flow through the by-pass meter. When the amount of water used exceeds a rate which would result in a pressure loss equal to 6 per cent of the inlet pressure, the valve shall open, and the water passing through the valve shall be recorded on the main meter. The valve shall contain a semi-hard rubber gasket for seating purposes.

Sec. 4–3.11—By-pass Check Valve

All meters shall be provided with check valves on the by-passes. The check valve interior mechanism shall be of bronze or other suitable non-ferrous material. They shall effectively prevent backflow and shall not bind or stick in service.

Section 4–4—Registration

The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent nor more than 103 per cent of the water actually passed through the meter while it is being tested at any rate of flow within the limits specified in Table 1, Column 5, under "Normal Test Flow Limits," except in the registration of flows within the "change-over" from by-pass meter to main meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change-over" shall not exceed the figures in the following table:

Meter Size, *in.*	Rate of Flow, *gpm.*
3	40
4	60
6	130
8	210
10	300
12	400

The beginning of the "change-over" is when the accuracy of registration falls below 97 per cent, due to the operation of the automatic valve mechanism, and the end of the "change-over" is when the accuracy of registration again reaches 97 per cent.

Not less than 95 per cent of actual flow shall be recorded when a test is made at the rate of flow set forth in Table 1, Column 4, under "Minimum Test Flow."

Section 4–5—Pressure Test

Meters shall be guaranteed to operate under a working pressure of 150 psi. without leakage or damage to any part. The check valves on main and by-pass meters shall be able to resist a back-pressure of 150 psi.

Section 4–6—Workmanship and Materials

Meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect has developed within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Section 4–7—Rejected Meters

The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

NOTES

These notes are not part of the specifications. They are given only as information concerning the testing and care of meters and important materials used in meter construction. They are not intended to limit in any way the future development of better materials for general use or the use of special metals with specific waters which may require materials of different composition to give service equal to that recorded in normal practice.

(1) *Tests*

Capacity tests are those which test the design of the meter. When a meter of a given design has once been tested for capacity, it should not be necessary to test this type of meter again unless a change has been made in the design.

Registration tests are those which test the assembly and workmanship of the meter. Each meter should be tested for registration, as there is no certainty that, because one meter of a given design is within certain limits of accuracy, all meters of this design will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and the purchaser in making registration tests.

All meters should be tested for accuracy of registration within, and as near as practicable to, the low and high rates given under "Normal Test Flow Limits," and occasionally additional tests should be made at one or more intermediate points. A test at the "Minimum Test Flow" should be made on all meters.

A pressure test should be made on each size of meter of a particular design furnished. This pressure is to be 150 psi. and may be obtained by the use of a hand pump or any method available. The meter should be tested for accuracy before and after it has been tested by static pressure to determine whether there has been any distortion that would affect the registration. It is unnecessary to make more than one pressure test on each size of a given design if satisfactory results are obtained. A working pressure test is preferable to a static pressure test.

If the purchaser has no testing equipment, a certificate should be furnished by the manufacturer showing that each meter has been tested for accuracy of registration, that it complies with the specifications and that the size and design comply with the capacity requirements.

(2) *Testing Equipment*

The minimum test equipment is as follows:

(a) A valve on the supply line which would permit the starting and stopping of the flow without appreciable loss of time.

(b) A valve or other suitable device on the discharge line which can provide the rate of flow desired.

(c) Pressure gages on supply and discharge pipes, so that any change in pressure which would affect the rate of flow can be detected. The discharge pipe must be under sufficient head to guarantee a pressure on the outlet of the meter.

(d) A measuring device of either the volumetric or weighing type. The accuracy of the determination of the amount of water discharged should be such as to bring the limit of error within 0.25 per cent. The amount of water passed should be sufficient to cause at least one revolution of the pointer on the initial dial except for the test at the "Minimum Test Flow" rate. The amount passed at the "Minimum Test Flow" rate should be of sufficient quantity to secure a true indication of the accuracy.

(e) Two piezometer rings of exactly the same diameter for capacity tests. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not fewer than four holes shall be provided, drilled in pairs on diameters at right angles to each other. The inlet ring shall be set close to the meter at a distance of eight diameters or more below the nearest upstream stop valve or fitting, and the outlet ring shall be placed at a distance of between eight and ten diameters from the outlet of the meter. The diameter of the rings, the inlet and the outlet pipes shall be the same as the size of the meter to be tested. The rings are to be connected to a mercury U-tube, equipped with an accurate adjustable scale for measuring the difference in mercury level, by rubber or metallic tubing. Provision is to be made for the complete removal of air from the U-tube and the tubing connected therewith, and the installation is to be such that air will rise to the air outlets. Where relatively high flows are to be measured, it is necessary to read both sides of the mercury column simul-

taneously in order to compensate for irregularities in the diameter of the glass U-tube and to avoid errors due to fluctuations.

Suitable pressure gages may also be used.

(3) *Care of Meters*

In a fire service meter the motions of the pistons and impellers are transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, as cubic feet or gallons. The gearing serves to translate the motion of the pistons and impellers into the unit of measure indicated by the registers. The register is at all times a measure of the number of revolutions of the pistons or measuring impellers in terms of cubic feet or gallons. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and after proper calibration will continue to register correctly only as long as the piston and impeller continue to make the proper number of cycles for each unit of quantity passed through the meter. If, after calibration, any condition should develop, whereby the pistons or impellers are compelled to make less than the proper number of cycles per unit of quantity passed through it, the meter will under-register. If the pistons or impellers are compelled to make more than the proper number of cycles, the meter will over-register. The proper number of cycles is the number made at the time the meter is calibrated. The measurement of flow recorded on the main unit, through which only a relatively small portion of the total flow actually passes, is likely to be inaccurate unless careful attention is given to keep all parts of the meter in the best working condition. Under ordinary working conditions, there are a number of factors that may cause under- or over-registration after comparatively short intervals. The more important of these factors which should be guarded against to secure proper registration are:

(a) *Excessive Wear.* Excessive wear of the moving parts of the meter may be caused by improper setting, by over-speeding or, in general, by the selection of a meter too small for the work required. The effect of excessive wear of the pistons, impellers or measuring chambers is slippage and under-registration. Excessive wear of the intermediate gear trains may cause binding of the gears or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should be set in a horizontal position and should not be run at destructive speeds. The capacity of the meters given in the specifications represents the maximum rates of flow at which water should be passed through the meters for short periods of time or the peak loads which should come upon meters only at long intervals.

(b) *Temperatures.* High temperatures cause expansion of the rubber pistons and impellers, which tends to create unusual friction or to bind the piston or impeller in its chamber. The effect is slippage and under-registration or failure of the meter. Low temperatures have no noticeable effect on the working parts of the meter. Freezing will stop the meter and possibly damage it.

Cold water meters are not affected by temperatures up to about 80°F. In warm climates, where the temperature of the water is likely to go above 80°F., meters with clearances slightly larger than ordinary should be used, and accuracies indicated in the specifications must be modified accordingly.

To avoid troubles caused by temperature, meters should be set at locations where they will be protected from heat and frost. At locations where the hot water from heating systems may be forced back through the meter, a check valve and temperature and pressure relief valve should be installed on the outlet side of the meter.

(d) *Corrosion.* All the metals used in the construction of a meter are affected by the corrosive action of water. The action is very slow with most potable waters. The result is that parts of the meter are weakened, particularly the teeth of the open intermediate gears, and, with meters that are idle for long intervals, there is a tendency toward binding. Tuberculation of the outer case in meters of the proportional type may change the normal direction of flow and cause inaccurate registration.

(d) *Material in Suspension.* Foreign material carried in suspension has a tendency to fill the space between the piston and measuring chamber and cause over-registration of displacement meters. Such over-registration, however, is limited and cannot generally exceed 3 per cent.

Accumulations of deposit always tend to cause inaccurrate registration of proportional

meters, as any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause inaccurate registration. Such inaccurate registration is not limited.

Sand is especially destructive, and care should be exercised to prevent sand from reaching the pipes supplying the meters.

The finer particles of suspended material cannot be prevented from reaching the meter, and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

(e) *Periodic Tests.* Meters properly selected as to size and type will give satisfactory service over a long period of time without attention only when operated under ideal conditions. Under ordinary conditions, meters must be given some care if they are to function properly. In most cases it is impossible to ascertain, without actual test, whether a meter which has been in service is registering within the required degree of accuracy. Consequently, to insure reliable meter measurements, it is essential that all meters be subjected to periodic tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under *average* conditions the following intervals between tests should not be exceeded:

Meter Size *in.*	Years Between Tests
3	3
4	2
6	1
8	1
10	1
12	1

Many state regulatory commissions specify the intervals between tests on both a time and quantity basis.

Meters of the fire service type used for measuring unfiltered surface waters should be cleaned about once a year in order that they may be kept in good working condition. When filtered or exceptionally clean water is used, the intervals between cleanings may be longer.

Best results will be obtained from fire service meters if they are calibrated in place, since the accuracy of these meters is affected by changes in distribution of velocities through the meter. A meter of this type, calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter, may register incorrectly from the start if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on the premises this source of error is minimized.

(4) *Bronze*

A bronze which is satisfactory for most waters is that of specifications B62–36 of the American Society for Testing Materials or No. 2 Federal Specifications QQ–B–691a for an alloy of copper, tin, lead and zinc, known commercially as composition metal, 85–5–5–5, ounce metal, red brass or hydraulic bronze.

(5) *Rubber*

A satisfactory rubber for pistons, measuring impellers and bushings should, among other items, have a specific gravity under 1.2, a minimum tensile strength of 6,500 psi., a maximum elongation of 5 per cent, a hardness (scleroscope test) of not less than 67, a free sulfur content of 3 per cent or less, a free ash content of not more than 3 per cent and a uniformity of cure and physical characteristics.